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Massachusetts Military Reservation

PLUME RESPONSE PROGRAM

Final
Fuel Spill-12
Interim Remedial Action Report

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ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
ANG	Air National Guard
AS/SVE	air sparging/soil vapor extraction
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of concern
CPR	Cardiopulmonary Resuscitation
CQP	Construction Quality Plan
CS	Chemical Spill
DEP	Department of Environmental Protection
DO	dissolved oxygen
DoD	Department of Defense
DQOs	Data Quality Objectives
DSMOA	Defense State Memorandum of Agreement
EDB	ethylene dibromide
EPA	Environmental Protection Agency
ERA	Environmental Restoration Account
ETR	extraction, treatment and reinjection
EW	extraction well
FS	Fuel Spill
FTA	Firefighter Training Area
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute
H_2O_2	hydrogen peroxide
HAZCOM	hazard communication
HAZOP	hazardous operations
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSP	Health & Safety Plan
IROD	Interim Record of Decision
IRP	Installation Restoration Program
JE	Jacobs Engineering
$KMnO_4$	potassium permanganate
LF	Landfill
LTM	Long-term monitoring
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MMR	Massachusetts Military Reservation
µg/L	microgram per liter
msl	mean sea level
NaOCl	sodium hypochlorite
NaOH	sodium hydroxide
NGB	National Guard Bureau
NPL	National Priorities List
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PHSM	program health & safety manager
PME	performance monitoring assessment
PPE	personal protective equipment
PRA	Preliminary Risk Assessment
psi	pounds per square inch
QA/QC	Quality Assurance/Quality Control
QPP	Quality Program Plan

RA	remedial action
RD	remedial design
RI	remedial investigation
ROD	Record of Decision
RW	reinjection well
SAP	Sampling and Analysis Plan
SD	Storm Drain
SPEIM	system performance and ecological impact monitoring
SVOC	semivolatile organic compound
TRET	Technical Review and Evaluation Team
USGS	United States Geological Survey
UTES/BOMARC	unit training equipment storage/Boeing Michigan Aerospace Research Center
UV/OX	ultraviolet/oxidation
VOC	volatile organic compounds
VPH/EPH	volatile petroleum hydrocarbons/extractable petroleum hydrocarbons

FS-12 Interim Remedial Action Report

1.0 INTRODUCTION

This Interim Remedial Action Report has been prepared by the Air Force Center for Environmental Excellence (AFCEE) for the Fuel Spill-12 (FS-12) extraction, treatment and reinjection (ETR) groundwater treatment system at the Massachusetts Military Reservation (MMR), Barnstable County, Cape Cod, Massachusetts. This report also discusses the air sparging/soil vapor extraction (AS/SVE) remedial system employed at the FS-12 source area.

Section 1.0 provides general information pertaining to all sites managed by AFCEE at the MMR and introduces the operable unit (FS-12) for which the report is written. Section 2.0 provides the regulatory framework and remedial design considerations for the remedial systems constructed for the FS-12 source area and groundwater plume. Section 3.0 provides a summary description of the activities undertaken to construct and implement the remedial systems and Section 4.0 summarizes the major events including significant milestones. Section 5.0 describes the performance standards and quality assurance/quality control measures related to the construction of the remedial systems at FS-12. Information regarding inspections and/or certifications is included in Section 6.0 and operations and maintenance activities are described in Section 7.0. A summary of project costs is included in Section 8.0. Section 9.0 provides observations and lessons learned during the design and construction of the remedial systems and Section 10.0 includes contact information for the organizations involved in the cleanup process. Appendix A includes all figures and tables referenced in the main body of the report and Appendix B provides references for documentation used in preparing this Interim Remedial Action Report for FS-12. Appendix C includes an inspection report prepared at the end of the construction and shakedown period.

1.1 General Description

The MMR occupies approximately 22,000 acres within the towns of Bourne, Sandwich, Mashpee, and Falmouth in the upper western portion of Cape Cod, Massachusetts (Figure 1-1) on two distinct types of terrain on the Cape Cod Peninsula. The main Cantonment Area lies on a broad, flat, gently southward-sloping glacial outwash plain. Elevation in the area ranges from 100 to 140 feet mean sea level (msl). To the north and west of the Cantonment Area, the terrain becomes hummocky with irregular hills and greater topographic relief, and lies in the southward extent of Wisconsin Age terminal moraines. The elevations north and west of the Cantonment Area generally range from 100 to 250 feet; the highest elevation reportedly is 306 feet [U. S. Army Corps of Engineers, 1995]. The entire site is dotted with numerous kettle holes and depressions, some of which contain water.

A single groundwater flow system, sole source aquifer, underlies western Cape Cod (from the Cape Cod Canal to Barnstable and Hyannis), including MMR. This aquifer system is described as unconfined (e.g., in equilibrium with atmospheric pressure) and is recharged by infiltration from precipitation. The highly permeable nature of the sands and gravels underlying the area allow for rapid infiltration of rainfall, which greatly reduces surface water runoff. The high point of the water table, or the top of the groundwater mound within the western Cape Cod groundwater system, is located beneath the northern portion of MMR. Flow is generally radially outward from this mound. The ocean forms the lateral boundary of the aquifer on three sides, with groundwater discharging into Vineyard Sound and Nantucket Sound on the south, Buzzards Bay on the west, and Cape Cod Bay on the north. The Bass River in Yarmouth forms the eastern lateral boundary.

Portions of the MMR have been used for military training purposes since 1911, with most activity occurring after 1935. The level of activity at MMR has varied over its operational history. MMR has been used for army training and maneuvers, military aircraft operations, maintenance and

support. Five military units currently operate at MMR including: Massachusetts Army National Guard (Camp Edwards), Massachusetts Air National Guard (Otis Air National Guard Base), U.S. Air Force, U.S. Coast Guard, and the Veterans Administration.

1.2 Operations and Waste Management Practices

Beginning in the 1930s, aircraft runways, aircraft and vehicle maintenance areas, landfills and firefighter training areas were used for military activities. Between 1955 and 1972, Air Force operations included the use of petroleum products and other hazardous materials such as fuels, motor oils, and cleaning solvents and the generation of associated wastes. Consistent with practices of other industries at the time, it was common practice for many years at MMR to dispose of such wastes in landfills, drywells, sumps, and the sewage treatment plant. Spills and leaks also occurred. These activities have resulted in serious impacts to the Upper Cape's groundwater resources. Today the generation, use, and disposal of hazardous materials is strictly managed and regulated to protect the environment.

1.3 Regulatory and Enforcement History

In 1982, the Department of Defense (DoD) initiated a multi-phase Installation Restoration Program (IRP) to identify and evaluate problems associated with past hazardous waste disposal and spills at DoD installations, including National Guard Bureau (NGB) facilities. An IRP office was established at the MMR in 1990. The IRP performs environmental restoration activities that follow the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidelines, and is conducted in seven stages, as follows:

- identification of potential hazardous waste sites
- confirmation of the presence of hazardous materials at the site
- determining the type and extent of contamination during the Remedial Investigation
- evaluation of alternatives for cleanup of the site in a Feasibility Study
- proposal of a clean-up remedy in a Proposed Plan
- selection of a remedy
- preparation of a Record of Decision (ROD)
- implementation of the remedy for cleanup of the site

Both private sector and federal facility sites are eligible for placement on the United States Environmental Protection Agency (EPA) National Priorities List (NPL). In July 1989, the EPA proposed MMR for inclusion on the Federal Superfund NPL. EPA formally added MMR to the NPL on November 21, 1989. Therefore, MMR is subject to the special provisions for federal facilities under the CERCLA Act of 1980.

Federal military sites such as MMR receive funding from the DoD Environmental Restoration Account (ERA) and not from the Hazardous Substances Superfund under CERCLA. On July 17, 1991, the Air National Guard (ANG) and EPA Region 1 entered into a Federal Facility Agreement that outlines clean-up policies and procedures at MMR. Also in 1991, a Defense State Memorandum of Agreement (DSMOA), a cooperative agreement between the DoD and the Commonwealth of Massachusetts, was issued to provide funding for state regulatory oversight.

1.4 Site Investigation Activities

Between 1982 and 1985, the IRP identified 73 areas of concern and recommended 21 sites be investigated first (Figure 1-2). Site investigations conducted at the 21 areas of concern discovered contaminants including volatiles organic compounds (VOCs), polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), semivolatile organic compounds (SVOCs), and waste oils and metals.

Investigations conducted to date have identified 15 groundwater plumes originating from MMR. These include Ashumet Valley, Chemical Spill 4 (CS-4), CS-10, CS-19, CS-20, CS-21, Eastern Briarwood, Fuel Spill 1 (FS-1), FS-12, FS-13, FS-28, FS-29, Landfill 1 (LF-1), Storm Drain 5 (SD-5), and Western Aquafarm. Most of these plumes have migrated beyond base boundaries.

Additional information regarding investigations at the areas of concern/sites and their remediation status can be found in the IRP Community Involvement Plan dated July, 2000. This plan is also available on the MMR website at www.mmr.org.

1.5 Removal and Remedial Activities

In 1992, the first MMR interim ROD (IROD) was signed for the CS-4 groundwater plume treatment system, which began operation in 1993. Also in 1992, a proposed plan was also submitted to the public outlining its proposed remedy to construct a multilayer capping system for 60 acres of the main base landfill (LF-1), the source of the LF-1 groundwater plume. The following year, an IROD was signed for three sections of the main base landfill (LF-1) and construction of the landfill caps was initiated.

In 1994 the IRP began to treat contaminated soil at several source areas, including CS-4. In 1995 an AS/SVE system was constructed and began operation to remove fuel from the FS-12 source area. Also in 1995, soil treatment at the former firefighter training area 1 (FTA-1) began and the landfill cap was completed. In addition, an IROD was signed for seven groundwater plumes—Ashumet Valley, CS-10, Eastern Briarwood, FS-12, LF-1, SD-5, and Western Aquafarm (ANG, September 1995). It was decided that all but two of the plumes would be remediated. Eastern Briarwood and Western Aquafarm would undergo long-term monitoring (LTM). In 1996, an evaluation of the 60% design for simultaneous containment of the groundwater plumes determined that it could not be accomplished without adversely affecting the ecosystem on the Upper Cape and the design was deemed environmentally unacceptable.

To address the 60% design issues, a specialized group referred to as the Technical Review and Evaluation Team (TRET) was established. The TRET includes environmental experts from the EPA, DEP, and the United States Geological Survey (USGS). They issued a report in May 1996, entitled "Toward a Balanced Strategy to Address Contaminated Groundwater Plumes at the Massachusetts Military Reservation' in which the TRET developed new design criteria and containment strategies and made recommendations to proceed with groundwater plume remediation efforts while avoiding adverse ecological impact. The National Guard Bureau brought in AFCEE, who contracted Jacobs Engineering for the design and construction of the groundwater treatment systems. AFCEE and Jacobs Engineering utilized the 60% design and the TRET report to design and build the FS-12 and SD-5N treatment systems. An additional process, referred to as the Decision Criteria Matrix, was implemented for subsequent remediation systems (i.e. LF-1, AVA, CS-10, and SD-5S) to allow for additional community input.

Also in 1996, 106 underground drainage structures containing contaminated liquid and sediments were removed. Over 30,000 linear feet of drilling for monitoring, extraction, and reinjection wells were completed for construction of the FS-12 and SD-5N groundwater treatment systems and various investigations. A pilot project began in two areas of the CS-10 plume, testing the effectiveness of two types of recirculating well technology and a carbon filtration unit for a municipal water supply well in the Town of Falmouth started operation.

Construction was completed in 1997 and operations began for the treatment systems at SD-5 North and FS-12 groundwater plumes. Also in 1997, a time-critical removal action was initiated to install a groundwater extraction well and treatment facility to capture the FS-28 plume of EDB at a high-concentration area, preventing upwelling into the Coonamessett River system. Also in 1997, the IRP completed the soil treatment project at the FTA-1, which resulted in the remediation of 42,000 tons of soil.

Intensive construction and operation activities for groundwater treatment began in 1999. Treatment systems were constructed and began operation at Ashumet Valley, LF-1, CS-10 Sandwich Road, and CS-10 In-Plume. Recirculating well treatment systems were installed underground and began operation to address a portion of the SD-5 South plume. In 2000, extraction wells were installed to remove contaminants from the CS-10 TCE plume and portions of the SD-5 South plume. The extracted water was treated by the existing system built for SD-5N. The CS-10 South/Southwest treatment system, a modification to the existing CS-10 In Plume treatment system, began operation in April 2000.

Also in 2000, two RODs were signed—one for four groundwater plumes (CS-4, CS-20, CS-21, and FS-13) and another for the FS-1 source area and groundwater plume. A proposed plan was released in February for the FS-28 and FS-29 groundwater plumes, and the Final ROD was signed in October 2000.

1.6 Operable Units and FS-12

Sections 1.4 and 1.5 provide information related to the other operable units (i.e. areas of concern/IRP sites) at MMR. There are numerous reports available in the IRP for these areas of concern/sites. A summary and brief description of these areas is available in the IRP Community Involvement Plan dated July, 2000. The plan and other IRP reports are available on the MMR website at www.mmr.org.

The focus of this Interim Remedial Action Report is the site FS-12. FS-12 is the location of a leak in an abandoned fuel pipeline along Greenway Road near the base border in the Town of Sandwich (Figure 1-3). Contamination associated with FS-12 was first discovered in 1990 when the Sandwich Water District detected hydrocarbon odors and VOCs, including benzene, in two exploratory wells installed off-base. The exploratory wells were installed as part of an effort to identify suitable locations for additional water supply production wells. The pipeline carried both jet fuel and aviation gasoline during its use from 1965 to 1973. The leak was reported to have occurred in 1972 where an estimated 70,000 gallons of petroleum was discharged from a section of fuel pipeline at the intersection of Greenway Road and the western entrance to L-Range. The primary constituents in the FS-12 plume are benzene and ethylene dibromide (EDB). These contaminants have been detected at concentrations exceeding the maximum contaminant levels (MCLs) of 5 micrograms per liter (ug/L) and 0.02 ug/L, respectively.

The release from the pipeline created a contaminated source area and a groundwater plume. This report primarily addresses the groundwater plume and the remediation system constructed to treat it. This report also provides information pertaining to the source area remediation, although to a lesser extent, since a source area removal action summary report has already been prepared and approved by the regulatory agencies (AFCEE, March 2000).

2.0 FS-12 BACKGROUND

Following the discovery of the contamination at FS-12, an investigation was initiated. The remedial investigation (RI) completed in 1993 concluded that fuel leaking from the pipeline contaminated soil and groundwater (ANG, January 1995). Free product was found in the vadose zone over a five-acre area at and south of Greenway Road. The FS-12 source area was subsequently identified as an 11-acre area of contaminated vadose zone soil, groundwater, and floating product. Fuel components dissolved in the groundwater and created a plume approximately 4800 feet long, 2000 feet wide, and between 60 to 130 feet thick. The FS-12 groundwater plume migrated downgradient off base and under Camp Good News, a privately-owned summer camp.

A Preliminary Risk Assessment (PRA) was conducted as part of the RI. The intent of the PRA was to determine if there were any threats to human or ecological receptors from the contamination present in soils or groundwater. This was accomplished by evaluating compounds detected during analytical sampling at the site to identify those which pose potential human or ecological risks and then quantifying the risk posed to possible human populations or ecological receptors. Calculated risk values were then compared to EPA carcinogenic and noncarcinogenic risk guidelines to determine if acceptable risk levels had been exceeded.

Contaminants of concern (COC) were selected based on compound concentration and resulting human exposures, compound toxicity, and often on the basis of compound prevalence alone. Risk was evaluated for groundwater exposures to area residents under current/future land use scenarios. Risk was also evaluated for subsurface soil exposures to a hypothetical utility worker under current and future land use scenarios. Reasonable maximum and most probable carcinogenic risk values calculated for current/future exposures to organic groundwater COCs were $1 \times 10^{+0}$ and 5×10^{-2}, respectively. Both values exceeded the EPA risk range (1×10^{-6} – 1×10^{-4}), indicating excess carcinogenic risk for human exposure to groundwater. It was determined that 99.9% of each of these risk values was due to the presence of EDB.

Inorganic groundwater COCs identified in the RI Report (ANG, 1995) included aluminum, arsenic, beryllium, cadmium, chromium, manganese, and nickel. Hexavalent chromium and arsenic were determined to be the largest contributor to reasonable maximum exposure (RME) carcinogenic risk attributable to inorganic compounds in groundwater. The RME carcinogenic risk and the most probable risk were determined to be 2×10^{-3} and 3×10^{-4}, respectively. The RME and most probable hazard indices (HIs) due to inorganic groundwater COCs were 30 and 3, respectively. These data were calculated for a land use scenario of current/future groundwater use by a utility worker. Because 99.9% of the risk values calculated were due to the presence of EDB, this organic contaminant and benzene were determined to be the primary COCs. The recommended remedial action objective in the RI Report stated "For groundwater, the RAOs include: prevent the ingestion of water with concentrations of benzene and EDB equal to or in excess of the MCLs."

Ecological exposures to COCs and resultant risk were also evaluated. It was determined that no complete pathway exists for ecological exposure. Without a complete pathway, no ecological exposures to COCs occur and no resultant ecological risk occurs.

The investigations conducted to support the design of the FS-12 groundwater remediation system began in July 1996 and continue through the present; the results of which have been presented in several reports, which are listed on the website.

Although the focus of this report is on the FS-12 groundwater plume remediation, the source area remediation efforts are briefly addressed throughout this report. Source removal at FS-12 was conducted as part of a time critical removal action in accordance with the National Oil and Hazardous Substance Contingency Plan. The Final Action Memorandum (AFCEE, November

1996) provides a written record of the decision process and rationale for the removal of jet fuel identified beneath the fuel pipeline via a combined AS/SVE system.

A pilot study targeting fuel-contaminated soils and shallow groundwater at the source area using AS/SVE technology was conducted during August and September 1993. A second pilot study targeting free product was conducted during the same timeframe using a recovery technology. The free product recovery technology was found to be ineffective at removing free product and was therefore not implemented. The AS/SVE system was determined to be a viable technology and a full-scale system was designed which commenced operation on October 23, 1995 and was shut down on February 25, 1998. Activities required to implement the AS/SVE system included:

- equipment purchase/lease and mobilization;
- site clearing;
- drilling and construction for 23 AS wells and 23 SVE wells;
- installation of underground piping;
- treatment system equipment installation;
- upgrade of existing area power from single-phase to three-phase;
- system start-up, monitoring and operation;
- closure sampling/analysis;
- waste management
- demobilization of system equipment; and
- restoration of site to original condition.

Detailed information related to the construction and operation of the AS/SVE system is provided in the Final FS-12 Source Area Removal Action Summary Report (AFCEE, March 2000). Following shutdown of the AS/SVE system in February 1998, the catalytic oxidizer was demobilized from the site and relocated to the UTES/BOMARC area for future use in other projects. The fencing and signage at the site has also been removed. All AS and SVE wells remain in the ground in order to use the wells for monitoring purposes. Currently, three of the SVE wells are sampled on a quarterly basis under the System Performance and Ecological Impact Monitoring (SPEIM) Program established for the FS-12 groundwater ETR system.

Closure sampling was conducted, in accordance with requirements specified in Appendix B of the Final Action Memorandum, as agreed upon by AFCEE, EPA, and the Massachusetts Department of Environmental Protection (DEP). Sampling involved the collection of 40 subsurface soil samples. Twenty samples each were collected within the vadose zone and the zone of saturation respectively. The soil samples were analyzed for Volatile and Extractable Petroleum Hydrocarbons (VPH/EPH), and EDB. Analytical results from all samples within the vadose zone were below the DEP Category Method 1 S-3/ GW-1 and Method 1 S-3/GW-3 soil cleanup standards (*310 CMR 40.0975*(*6*)(b)). Two of the 20 soil samples collected below the water table contained contaminants (VPH and EPH) at concentrations above DEP soil cleanup standards.

Soil boring locations were chosen to evaluate the effectiveness of the remediation system within the estimated source area and along the perimeter of the source area. Soil borings, when possible, were located in areas where soil analytical data existed and/or free product was detected prior to operation of the remediation system to allow for a more quantitative determination of the effectiveness of the remediation system.

In a March 1,1999 letter to AFCEE regarding FS-12 source area closure, the EPA and DEP agreed that elevated levels in the zone of saturation would not be effectively addressed by continued operation of the AS/SVE system. As a condition to shutdown of the AS/SVE system at the FS-12 source area, AFCEE agreed to monitor ten selected groundwater-monitoring wells on a semi-annual basis as part of the existing FS-12 performance monitoring evaluation (PME) program. During initial sampling of these 10 wells, three of the wells were unable to be sampled. Therefore, a decision was made, with concurrence from the regulators, to add an additional well

and to eliminate these three wells from the FS-12 PME program. Thus, a total of eight wells were added to the FS-12 PME program for source area monitoring, and the results are included in the applicable quarterly reports submitted to the regulatory agencies. Based on results of groundwater and soil closure sampling, the scope of work as specified in the Action Memorandum has been completed to the extent practicable with the condition that post-closure groundwater sampling be conducted as part of the FS-12 monitoring program.

2.1 Record of Decision Requirements

As stated in the *Record of Decision for Interim Action Containment of Seven Groundwater Plumes*, which includes the FS-12 plume, the interim remedial action is designed to intercept the contaminated groundwater plumes to prevent further downgradient movement of the contaminants (ANG, September 1995). It also states that extraction and treatment will continue until the final remedy for the site is chosen. The interim and final remedies must be consistent with the clean-up goals for the entire MMR site.

In summary, the interim remedy provides for:

- extracting contaminated groundwater at the leading edge of the contaminant plume and potentially extracting groundwater from hot spot areas identified during remedial design;
- pumping and conveying the extracted groundwater to a treatment system to remove contaminants;
- discharging the treated water back to the groundwater and/or other beneficial use;
- installing monitoring wells, measuring water levels, and sampling groundwater to monitor the performance of the extraction system;
- sampling the influent and effluent of the treatment system to monitor its performance;
- restricting groundwater use within the areas contained by the ETR through imposition of institutional controls; and
- conducting a review after five years of operation to ensure the remedy provides adequate protection of human health and environment.

<u>Cleanup Goals</u>

The long-term clean-up goals for reducing contamination in the groundwater at MMR are to meet Federal MCLs, non-zero Federal MCL Goals (MCLGs), Massachusetts MCLs, or risk-based guidance levels for compounds for which drinking water standards have not been set. For the FS-12 COCs, the cleanup goal established for EDB is the Massachusetts MCL of 0.02 ug/L and the cleanup goal for benzene is the federal MCL of 5 ug/L. Groundwater containing concentrations of contaminants exceeding these cleanup levels is extracted and treated to nondetectable concentrations. Furthermore, restoration of the aquifer in a reasonable timeframe has also been set at MMR as a cleanup goal.

In order to meet these goals, the IROD indicated that the rate of groundwater extraction and reinjection of treated water may require adjustments. It also required that the treatment system be designed and operated to ensure that all water discharged attains the cleanup goals.

In addition, there are guidelines related to protection of the ecosystems (i.e. Snake Pond and Week's Pond) near the FS-12 ETR. These guidelines were established through discussions with the regulatory agencies and a specialized group referred to as the Technical Review and Evaluation Team (TRET), which includes environmental experts from the EPA, DEP and the United States Geological Survey (USGS). The TRET established the guidelines in response to the 60% design, which resulted in unacceptable impacts. These guidelines, which were not included in the IROD, are as follows:

- pond water level cannot be changed by more than 0.5 ft;
- operation of the ETR system cannot produce more than a 20% change in the total groundwater discharge to the ponds; and
- a maximum of 25% of the total groundwater discharge to the ponds can be treated water

Institutional Controls

The IROD does not specifically address institutional controls aside from stating in general that groundwater use should be restricted within the areas contained by the ETR. Controls instituted in association with FS-12 include connecting potentially impacted homes to Sandwich Water District water and providing periodic testing of downgradient, potentially-impacted, residential wells at no charge to the property owners.

Monitoring Requirements

As with the institutional controls, the IROD did not specifically describe the monitoring program. It stated that "monitoring wells, which will serve as the points of compliance for this interim remedial action, will be located downgradient of the extraction wells at each plume." It also stated that monitoring wells will be installed, water levels will be measured, and groundwater will be sampled to measure the performance of the ETR. The IROD further stated that monitoring will also be conducted to evaluate the reduction in contaminant concentration and the effectiveness of the containment systems.

The monitoring program instituted at FS-12 for the groundwater ETR at MMR initially consisted of two monitoring programs: Performance Monitoring Evaluation (PME) and Ecological Impact Monitoring. In 2000, these two programs were combined into the System Performance and Ecological Impact Monitoring (SPEIM) Program. It includes monitoring of the treatment plant, groundwater monitoring wells, extraction wells, and surface water for chemical and/or hydraulic data. The monitoring is further described in subsequent sections of this report.

Operation and Maintenance Requirements

The IROD specified that the contaminated groundwater would be extracted from the aquifer, pumped to a treatment system, treated to remove the contaminants, then returned to the aquifer or used in another beneficial manner. This describes the operation of the ETR system. The IROD also specified that the influent and effluent of the treatment system would be monitored to ensure the system is performing as designed and that treated water must be discharged back to the subsurface to minimize the impact of water withdrawals on groundwater levels, possibly at locations downgradient of extraction wells.

The IROD also calls for a review every five years of ETR system operation to ensure the remedy provides adequate protection of human health and the environment. These reviews are intended to:

- provide a history of the operations of the treatment system over the previous five years;
- present the sampling results from the treatment system, performance monitoring activities, and ecological monitoring activities;
- present an evaluation of the five years of operation, including as assessment of whether the system has performed according to expectations and objectives; and
- recommend the need, if any, for modifications to the system or operating parameters.

The treatment system will be closed upon approval by the regulators, which is expected to be granted when the plume has been cleaned up to background levels (if technically and economically feasible), or when the required five year reviews present sufficient data to demonstrate that further operation of the systems is unfeasible to achieve further reductions in

contaminant levels. The IROD anticipated the operation of plume containment strategies at MMR would be for 20 years, by which time final remedy would be determined

Design and Construction Requirements

The IROD was not specific in these requirements; however, it stated in general terms that the interim remedial action will intercept the groundwater plume to prevent further downgradient movement of contaminants.

Following the IROD, AFCEE developed a Strategic Plan (AFCEE, July 1996) which proposed the installation of a groundwater remediation system at FS-12 to capture as near to 100% of the plume as possible without serious impact to the environment. The objectives for FS-12, as outlined in the Strategic Plan, included:

- design, construct, and operate a full-scale ETR system;
- contain, capture, and remediate the FS-12 plume;
- minimize adverse impacts on Snake Pond and its surrounding environment;
- monitor performance of the treatment system;
- avoid influencing the downgradient J. Braden Thompson plume;
- minimize disturbance to private property; and
- monitor groundwater quality to assess performance and assist future design at other sites.

2.2 Basis for Determining Cleanup Goals

2.2.1 FS-12 Source Area

The basis for determining cleanup goals of the FS-12 source area AS/SVE system is described in the FS-12 Source Area Removal Action Summary Report (AFCEE, March 2000).

2.2.2 FS-12 Groundwater Plume

The objectives of the plume remediation system were defined in the IROD and were used as the basis for determining cleanup goals. The objectives are described as follows:

- reduce the risks to human health associated with the potential future consumption and direct contact with groundwater and surface waters;
- protect uncontaminated groundwater and surface waters for future use by minimizing the migration of contaminants;
- reduce potential ecological risks to surface waters and sensitive coastal water through the implementation of the containment system; and
- reduce the time required for aquifer restoration.

The area surrounding MMR resides in Barnstable County, one of the fastest growing counties in Massachusetts. No determination has been made as to what the future land use will be for the reservation once the Army's lease with the Commonwealth of Massachusetts ends in 2026. It is unlikely that the entire base would be turned over for unrestricted use by the public since past military operations included, among other practices, the firing of artillery and mortar rounds into an Impact Area. However, it is assumed that if the base becomes private property, the majority of property would become residential. It is also assumed that Camp Good News will continue operating in the future as a youth camp and that additional construction could occur in the path of downgradient plume migration.

2.3 Remedial Design

2.3.1 FS-12 Source Area

The remedial design and construction of the FS-12 source area AS/SVE system is described in the FS-12 Source Area Removal Action Summary Report (AFCEE, March 2000).

2.3.2 FS-12 Groundwater Plume

The FS-12 ETR system design initially consisted of a network of 30 extraction wells (EWs) pumping at a design rate of 830 gallons per minute (gpm) and 30 reinjection wells (RWs) . The computer modeling that provided the basis for that network was described in the *Plume Containment Design Groundwater Modeling Report* (OpTech, August 1996). Through additional data collection, modeling, and value engineering, the installed wellfield configuration became one with 25 EWs, pumping at a rate of 762 gpm, and 23 RWs. EWs 1-5 were not used. Three of these EWs (1-3) were installed but not connected to the system; their casings and screens remain in the ground on the north end of Snake Pond. EWs 4 and 5 were never installed. RWs 1-4 were never installed since EWs 1-3 were not needed. Also, RWs 11 and 12 could not be installed due to steep terrain.

After startup on 18 Sep 97, the 10 gpm pumping rate at two EWs (EWs 20 and 21) was increased by 5 gpm each to achieve design rates. The refined FS-12 ETR system then pumped 772 gpm from the aquifer using 25 EW and returned the treated water to the aquifer via 23 RWs (Figure 2-1). The final FS-12 ETR design, based on modeling results, included:

- eleven EWs across the width of the plume near its downgradient extent (i.e. the southern toe extraction fence);
- fourteen EWs located in or near the center of the plume where contaminant concentrations are highest (i.e. the axial extraction fence);
- extraction of contaminated groundwater at 772 gpm and transfer of the groundwater from the EWs through double-walled high-density polyethylene pipe to an influent (equalization) tank;
- pH adjustment of influent;
- greensand filters to remove suspended solids, iron, and manganese;
- solids settling and collection facilities;
- an ultraviolet/oxidation (UV/OX) system to oxidize organics (i.e. EDB and benzene)
- a granular-activated carbon (GAC) system to reduce the organic contaminant concentrations to below the detection limit;
- return of the treated water to the aquifer through 23 RWs situated between the axial EWs and Snake Pond and downgradient of the southern toe extraction fence
- 99.99% capture

The extraction rate was increased to 782 gpm as a result of an evaluation of system performance and recalibration of the groundwater model as summarized in the *Second Quarter 1998 Fuel Spill (FS-12) Performance Monitoring Evaluation (PME) Data Report* (AFCEE, October 1998).

In addition to the ETR design, consideration was given to capturing additional modeled particles that would not be captured by the 25 planned EWs. These particles were located on the eastern side of the FS-12 groundwater plume and represented groundwater particles that may escape capture. To address these particles, AFCEE conducted the FS-12 Phase II Investigation, the results of which are reported in the *Final FS-12 Phase II Tech Memo* (AFCEE, May 2000). Phase I was the construction of the ETR system.

The Phase II Tech Memo summarized the results of the FS-12 Phase II June, August, and December 1998 groundwater sampling, modeling, engineering/pumping capacity evaluation, and focused risk evaluation, and presented the recommendations for Phase II actions. No additional

action was taken to capture these particles based on the effectiveness of the Phase I design (99.99%) and the result of the risk evaluation which concluded that EDB residuals present no unacceptable risk to human health.

Additional changes to the ETR system began with the detection of EDB above the MCL in a Snake Pond microwell, ECMWSNP02D in September, 1999 (Figure 2-2). Subsequent sampling events detected EDB in both the shallow (S) and deep (D) screens of the microwell. The shallow screen, 02S, is five feet long and is 45-50 feet below the bottom of Snake Pond. The deep screen, 02D, is also five feet long and is 80-85 feet below the bottom of the Pond. A second microwell located within the Pond, ECMWSNP03, also has a shallow and deep screen. The shallow screen, 03S, is located 40-45 feet below the bottom of the Pond and the deep screen, 03D, is located 80-85 feet below the Pond. Following additional monitoring related to these EDB detects which included sampling of existing monitoring wells and installing/sampling new monitoring wells along with additional groundwater modeling, three zones of EDB were defined to the west of the main FS-12 plume (Figure 2-3).

Based on the modeling scenarios generated along with piping simulations and field tests, the ETR system at FS-12 has been modified. EWs 6 and 10 were turned off in early June to allow for additional pumping from the axial extraction wells 14 through 19. EW6 no longer removes contaminants as it is outside of the plume boundary due to the collapse of the plume by the ETR system. The contaminants captured by EW10 will be captured by EW11. Overall, the ETR pumping rate was increased to approximately 800 gpm in order to slow the EDB migration under Snake Pond and prevent the EDB detected in microwell 02S from potentially discharging to Snake Pond. On 25 Jul 00, RWs 5 - 9 were turned off and the reinjected flow was distributed throughout the remaining reinjection wells, with greater flow to the eastern and western ends of the reinjection fence.

A contract was awarded to Jacobs Engineering in December, 2000 to design and construct a treatment system to remediate the EDB contamination identified in the three zones west of the FS-12 plume. The design involves modifying the existing FS-12 treatment system. An existing reinjection well (RW10) will be converted into an extraction well. The contaminated groundwater will be pumped at approximately 95 gallons per minute (gpm) through a new six-inch double walled extraction pipe that will be connected to the existing extraction header that transfers extracted groundwater to the existing FS-12 treatment plant where it is treated using granular activated carbon. The treated water will be returned to the aquifer through the existing reinjection header. This conversion project will also require changing the flow rates of other extraction and reinjection wells. Overall, the existing FS-12 treatment system, along with the modification will pump approximately 800 gpm.

The remedial action is expected to capture 97.2% of the EDB contamination in the zones with the remaining contamination partially discharging to Snake Pond (shallow contamination) and partially bound up in the silts (deep contamination). Construction was initiated in April 2001, with system start up scheduled for June 01, 2001. The system modification is expected to operate for approximately three years.

2.4 ROD Amendments

To date, there have been no amendments to the IROD. AFCEE and the regulatory agencies are currently discussing plans to develop a Final ROD for FS-12 and other groundwater plumes.

3.0 CONSTRUCTION ACTIVITIES

3.1 FS-12 Source Area

The remedial design and construction activities of the FS-12 source area AS/SVE system are described in the FS-12 Source Area Removal Action Summary Report (AFCEE, March 2000).

3.2 FS-12 Groundwater Plume

This section provides information on construction and monitoring activities associated with the FS-12 groundwater ETR system.

<u>Construction</u>

Preconstruction activities consisted of acquiring applicable construction permits and access to private property. Utilities were contacted and coordinated. Staging areas were established and traffic flow patterns were developed while considering easement restrictions and minimizing traffic through residential areas. Pre-mobilization meetings and underground utility clearances were conducted. Additional data was collected through installation of new monitoring wells and analyzed to determine if additional pump tests were needed prior to construction (AFCEE, December 1997).

Table 3-1 provides a detailed chronological summary of the activities involved in the construction of the FS-12 groundwater plume ETR system.

<u>Monitoring</u>

The initial monitoring program developed for FS-12 was referred to as the PME program; its objectives were (AFCEE, December 1997):

- measure the piezometric surface generated by the extraction well and injection well fence to evaluate the effectiveness of vertical and horizontal capture;
- provide temporal and spatial piezometric and groundwater quality information necessary to guide adjustments to system performance to maintain adequate capture of the contaminant plume in response to changing hydraulic conditions and plume geometry
- provide groundwater quality data within the plume to assess contaminant trends due to system stresses, natural attenuation, and the migration of the more contaminated portions of the plume as they approach the extraction fence;
- provide groundwater quality data downgradient of the extraction well fence to monitor that contaminant capture at Federal and State MCLs is maintained;
- provide general water chemistry (physicochemical parameters) data downgradient and side gradient (particularly adjacent to Snake Pond) to assess potential impacts to groundwater chemistry due to system operation; and
- measure groundwater flow paths induced by the containment system to identify groundwater flow toward or away from Snake Pond.

Baseline performance monitoring was conducted prior to system startup. That data was used in determining the pre-start conditions for hydraulic gradients, static water levels, distribution and concentration of COCs, and general water chemistry.

The monitoring program developed for the FS-12 system included treatment plant performance monitoring, direct impact monitoring, ecological and plume monitoring. The sampling was conducted in accordance with the *Final Performance Monitoring Evaluation Plan for Fuel Spill-12* (AFCEE, April 1998), *Final Work Plan for Ecological Assessment Associated with Groundwater*

Plumes and Remedial Activities (AFCEE, April 1998), *and Final Fuel Spill-12 Groundwater Plume Phase II Pre-operational Ecological Sampling Plan* (AFCEE, August 1998).

Treatment Plant Performance Monitoring

FS-12 treatment plant performance monitoring consists of the collection and interpretation of treatment plant analytical data in order to monitor the efficiency of the FS-12 treatment plant. The effectiveness of the ETR system's ability to remove contaminants from the plume and return treated water that is similar in groundwater chemistry to that of the aquifer is determined. Analytical samples are collected on a monthly basis for VOCs, EDB, total organic carbon, manganese, total iron, total dissolved solids, and total suspended solids. Water quality parameters (pH, dissolved oxygen, temperature, oxidation-reduction potential, specific conductance, and turbidity) are also measured.

Plant Direct Impact Monitoring

Plant direct impact monitoring includes monitoring select upgradient monitoring wells and reinjection wells monthly for physicochemical parameters and micronutrients to determine what direct impacts the treatment system is having on these parameters. Physicochemical and field parameters are analyzed to assess the differences in chemistry between the groundwater in the aquifer and the treated water before it is reinjected. The physicochemical parameters include alkalinity, dissolved organic carbon, total nitrogen, ammonia, nitrate, nitrite, total phosphorous, total phosphate, and total organic carbon. Field parameters include temperature, dissolved oxygen, turbidity, oxidation-reduction potential, specific conductance, and pH.

It is important to note that the direct impact monitoring was changed in December 2000 and the upgradient wells have been replaced by plant influent sampling. Plant influent and effluent are now compared directly and provide a better understanding of changes to the extracted groundwater possibly induced by the treatment system itself.

Ecological Impact Monitoring

Ecological impact monitoring focused on the potential impacts to groundwater and surface water from the reinjection of treated groundwater. These impacts were assessed by analyses of the plume characteristics, groundwater quality, and surface water quality and included quantitative assessments of field parameters and nutrients, the pond trophic state as a measure of overall health, and the plume contaminant concentrations and water quality.

Plume Monitoring

Additional monitoring was performed to further delineate the FS-12 groundwater plume and track temporal and spatial concentration changes. This monitoring included sampling selected wells within the plume, sidegradient around the plume, and downgradient of the toe extraction fence. Most monitoring was conducted on a quarterly frequency and samples were analyzed for VOCs and EDB. In addition, eight source area wells were selected to add to the plume monitoring program.

4.0 CHRONOLOGY OF EVENTS

Table 4-1 provides a tabular summary that lists the major events for the FS-12 groundwater plume and source area actions. The table includes significant milestones and dates, such as, report submittal dates, treatment system startup, system modifications, and final shut-down of source area remedy. Significant milestones regarding construction activities can be found in Table 3-1.

5.0 PERFORMANCE STANDARDS AND CONSTRUCTION QUALITY CONTROL

5.1 Overall Performance and Cleanup Goals

The following information was extracted from the *Final Fuel Spill-12 Treatment System 1999 Annual System Performance and Ecological Impact Monitoring Report* which is the most comprehensive monitoring document for the FS-12 groundwater plume at the time of this report (AFCEE, January 2001).

Long-term monitoring shows that the FS-12 ETR system has been and continues to be effective in capturing and treating the FS-12 plume. Hydraulic and chemical data indicate that the plume's migration has been stopped at the southern toe extraction fence and contaminant concentrations upgradient of this extraction fence are decreasing. Potentiometric maps of data collected in 1999 indicate that the axial extraction wells have created a local groundwater depression in the center of the FS-12 plume. The southern toe extraction fence created a localized stress that was supported by reinjection stress further downgradient. Vertical gradients near the southern extraction fence suggest potential flow toward the extraction fence, and therefore indicate capture. The FS-12 ETR system's effectiveness in capturing contaminants was verified through groundwater modeling. The FS-12 residual plume front that was left uncaptured after system start-up was sporadically detected downgradient of the southern toe extraction fence, as predicted.

The FS-12 ETR system has significantly reduced the magnitude and volume of the plume as shown in Figures 5-1and 2-3. Figure 5-1 shows the FS-12 plume as drawn initially in 1996 and1997 as part of the basis of design. Figure 2-3 shows the FS-12 plume as drawn in 2000. EDB concentrations in monitoring wells in the plume's core have declined from several hundred to the highest concentration of approximately 30 μg/L. Plant influent concentrations support the apparent removal of the high concentration core of the plume. Monitoring wells used to assess plume width, combined with interpolated groundwater flow lines and groundwater modeling results, suggest that the central and northern portions of the plume have narrowed. The treatment system influent concentrations of EDB continue to exceed the MMCL of 0.02 ug/L with an average EDB influent concentration was 5.9 μg/L during 1999. The system effluent COC concentrations have been consistently nondetect. Please refer to Section 2.3.2 for discussion concerning the EDB zones located to the west of the main FS-12 Plume.

Groundwater results were compared to drinking water standards; several locations exceeded MMCLs during 1999. EDB was detected at four locations outside of the FS-12 plume boundary as defined (Figure 2-2); two of these detections exceeded the MMCL of 0.02 μg/L. EDB was detected in December 1999 in monitoring wells 90MW0089E and 90MW0089F at concentrations of 0.042 μg/L and 0.012 μg/L, respectively, 1,500 ft downgradient of the southern toe extraction fence. Monitoring well 90MW0077, which had detectable levels of EDB in June 1999 of 0.013 μg/L and in September 1999 of 0.014 μg/L, had no detectable levels of EDB in December 1999. These detections are consistent with model predictions made in 1996 and 1998 and were likely the result of the residual plume downgradient of the southern toe extraction fence, not by extraction fence breakthrough. An assessment of system effectiveness indicated the FS-12 ETR system was performing as designed, with sufficient drawdown to capture the FS-12 plume. The assessment concluded that the average operational conditions were sufficient to complete plume capture.

EDB was also detected in microwell ECMWSNP02D in September, 1999 at a concentration of 0.110 μg/L. Section 2.3.2 describes subsequent activities at FS-12 due to this detection.

5.2 Material Treated and Data Collection

5.2.1 Material Treated

The COCs removed by the FS-12 ETR system are EDB and benzene. A mass of 300 pounds of EDB was estimated to be present in the FS-12 groundwater plume; no estimates were calculated for benzene since EDB was primarily the human health risk driver. The COC mass removal rate is listed in Table 5-1. The monthly mass removal rate has continued to decrease and is currently at approximately 1.0 pound per month for EDB and less than 0.1 pounds per month for benzene. The FS-12 ETR system has removed approximately 120.4 pounds of EDB and 71.7 pounds of benzene from system start-up in September 1997 through December 2000 and has treated 1.26 billion gallons of groundwater.

The mass of the COC removed from the FS-12 plume, determined by the treatment plant influent concentrations and extraction well flow rates, during years 1997 through 2000 indicate that contaminant mass removal rates have declined. The system performance relative to mass removal has stabilized and reached a low removal capability because, in general, the core of the plume has been removed from the aquifer and average plume concentrations have significantly declined. This is supported by (1) decreasing plant influent concentrations; (2) decreasing concentration trends in monitoring wells in the core of the plume; and (3) groundwater modeling results that suggest that groundwater from outside of the plume margins should now be arriving at select extraction wells. It is expected that the system mass removal rate will continue to decline over time until the residual COC concentrations are below MMCL.

5.2.2 Data Collection and Assessment

The following discussion details methods for collecting analytical data, assessing system performance and assessing ecosystems for the Fuel Spill-12 Treatment System Performance and Ecological Impact Monitoring Reports. The sampling was conducted in accordance with the *Final Performance Monitoring Evaluation Plan for Fuel Spill-12* (AFCEE, April 1998), *Final Work Plan for the Ecological Assessment Associated with Groundwater Plumes and Remedial Activities* (AFCEE, April 1998), and *Final Fuel Spill-12 (FS-12) Groundwater Plume Phase II Pre-operational Ecological Sampling Plan* (AFCEE, August 1998) and the QPP (AFCEE, January 1998).

Results of all sampling and analyses efforts are documented in periodic PME and SPEIM reports. The documents are listed on the MMR website and also provided in Table 4-1. Many of these documents include Data Summary Reports which analyze the data using standard QA/QC measures.

Remedial system performance monitoring includes assessing the extraction and reinjection systems and their influence on the aquifer and on plume characteristics. It includes both hydraulic monitoring (i.e. groundwater elevation and flow direction, horizontal/vertical gradients) and reinjection impact monitoring (hydraulic and water quality impact of the reinjected water on the aquifer).

FS-12 treatment plant performance monitoring consists of the collection and interpretation of treatment plant analytical data in order to monitor the efficiency of the FS-12 treatment plant. Treatment plant performance monitoring is used to evaluate the treatment effectiveness (contaminant removal) and to return treated water that is similar in groundwater chemistry to that of the aquifer. Performance monitoring also includes plant direct impact monitoring where select upgradient monitoring wells and reinjection wells were monitored monthly for physicochemical parameters and micronutrients to determine the impacts of the treatment system on these parameters.

The results of the plant direct impact monitoring demonstrated that there were differences between the upgradient groundwater and the effluent, but these differences reflect an improvement in the quality of water reinjected into the aquifer. Parameters such as total organic carbon and dissolved organic carbon were lower in the effluent, as would be expected by a groundwater treatment system that removes organics from the influent waters. Dissolved oxygen (DO) was significantly higher in the effluent, indicating that the water was oxygenated prior to reinjection, and pH was high in the effluent, perhaps indicating that there was some residual anion exchange with the treatment carbon. Therefore, there were significant differences between the upgradient groundwater chemistry and the effluent of the FS-12 ETR, but these differences are more likely to improve the quality of the water as it is reinjected into the aquifer. In December 2000, the upgradient monitoring wells were replaced by the treatment system influent in order to better understand the impact of the treatment system on the groundwater. Influent and effluent values will be compared rather than upgradient groundwater from select monitoring wells and effluent.

Groundwater modeling was conducted to assess the potential impact of unusually high groundwater elevations during the spring of 1998 on wellfield performance. Recalibration of the groundwater model to the observed groundwater elevations and simulation of operating conditions indicated that the FS-12 ETR system was performing as designed.

5.3 Construction Quality Assurance and Quality Control (QA/QC)

All activities associated with the construction, operation, and monitoring of the FS-12 ETR system were performed in accordance with practices and procedures as detailed in *the Quality Program Plan* (QPP) (AFCEE, January 1998), which contains the Health and Safety Plan (HSP), the Sampling and Analysis Plan (SAP), and the Construction Quality Plan (CQP). The CQP detailed quality control activities that were to be carried out during construction and ensured that completed work met or exceeded design criteria, plans, and specifications so that all quality objectives were met. Any problems or deviations were addressed through nonconformance reports which documented the details in order to remedy the problem.

Not only were the remedial action contractors responsible for ensuring QA/QC procedures were followed but AFCEE also provided in house as well as Title II services for construction oversight.

5.4 Data QA/QC and DQOs

5.4.1 Data QA/QC

The MMR QPP was developed in accordance with U.S. Environmental Protection Agency-New England, Region I Compendium of Quality Assurance Project Plan Guidance (September 1998 Draft Final) and is intended for use as a generic program-wide document. This generic QPP combines all the elements of AFCEE's Model Field Sampling Plan (version 1.1) and the *AFCEE Quality Assurance Project Plan* (version 3.0) into one document.

This QPP is applicable to all work performed at MMR on behalf of AFCEE. It outlines the program's quality objectives, and describes a comprehensive set of sampling, analysis, QA/QC, data validation and assessment guidelines. Although generic in content, specific requirements are established that must be acknowledged prior to conducting work at MMR. Project- or task-specific information not covered by this QPP must be documented in project-specific planning documents.

5.4.2 Data Quality Objectives (DQOs)

A systematic project planning process results in DQOs which ensure that the correct type, quality, and quantity of data are collected for the respective investigation. DQOs ensure that the proper data are collected and generated to answer environmental questions regarding a specific

environmental problem. Environmental monitoring activities at MMR have been divided into numerous categories: risk management monitoring including monitoring residential wells and water supply sentry wells; monitoring of plume nature and extent; monitoring of source areas; remedial system performance including in-plant monitoring and system performance and ecological impact monitoring; and remedial investigations.

5.5 EPA Oversight Activities

While EPA, Region I has CERCLA authority at MMR, DEP also participates as a full partner in the IRP process. The EPA and DEP personnel provided regulatory review and oversight for design, construction, and operational phases of the removal action at the source area. Final plans and specifications for the FS-12 source area remediation system, issued in July 1994, were reviewed and approved by regulatory personnel.

The EPA and DEP personnel also provided the same oversight for the FS-12 groundwater plume remediation project. They were updated frequently at weekly technical meetings and reviewed/commented on investigation and design documents.

The IRP office continues to keep the regulatory agencies informed of system operations and maintenance, monitoring, and system modifications. In addition, the regulatory agencies review quarterly and annual reports, in which proposed changes to the existing systems or monitoring networks are discussed. The proposed modifications are discussed and implemented with regulatory concurrence.

6.0 FINAL INSPECTION AND CERTIFICATIONS

6.1 Remedial Action (RA) Contract Inspections

Section 5.3 described the QA/QC followed for construction of the FS-12 ETR system. Inspections were conducted throughout the construction phase by contractors, AFCEE personnel, and Title II services (Appendix C). Nonconformance reports were prepared any time a condition exists that does not comply with drawings, specification codes, workmanship standards, or Air Force contract requirements. The inspectors were required to document all discrepancies that could not be corrected immediately. Final acceptance reports were filed to detail required re-testing, examinations, or changes in identification of any replacement parts used in correcting the problem.

Turnover packages are used to document the inspection and testing of equipment and facilities. Each package contains pertinent drawings, process and instrument diagrams, process flow diagrams, QA/QC checklists, punchlists and sign-off sheets. This turnover system allows for a step-by-step inspection, testing and turnover of each system and subsystem to ensure the smooth start-up and commissioning of the entire plant. The following FS-12 components had turnover packages:

- each EW and RW;
- collection system pipelines;
- compressed air system;
- fire detection system;
- potable water system, including safety showers and eye wash stations;
- containment system;
- influent system, including tank, pumps, instruments, pH system;
- carbon units;
- UV/OX system;
- sedimentation tank;
- effluent tank, including pumps and piping;
- hydrogen peroxide system;
- sodium hypochlorite system;
- sodium hydroxide system;
- landscaping and fencing; and
- building and architectural features, including concrete test data and structural data

6.2 Health and Safety

The prime contractor responsible for designing and construction the FS-12 ETR system was Jacobs Engineering (JE). JE has a strict health and safety program which adheres to hazard communication programs, safety training, medical surveillance programs, and personal protective equipment.

Hazard Communication

JE Employee Hazard (HAZCOM) Communication training includes at a minimum:

- methods and observations that can be used to detect the presence or release of a hazardous chemical in the work area (such as the kind of monitoring conducted by O&M personnel, continuous monitoring devices, and visual appearance or odor of hazardous chemicals);
- the physical and health hazards of the chemicals in the work area; and
- the measures employees can take to protect themselves from these hazards, including specific procedures implemented to protect employees from exposure to hazardous

chemicals, such as appropriate work practices, emergency procedures, and proper personnel protective equipment.

Plant chemical hazard information is be provided to all potentially affected personnel. Information concerning specific chemical hazards and the appropriate protective measures are provided by:

- developing and maintaining a written hazard communication program for the workplace, including lists of all hazardous chemicals present;
- properly labeling chemical containers;
- distributing Material Safety Data Sheets; and
- developing and implementing employee training programs on the hazards of chemicals and protective measures

Safety Training:

All personnel involved with the construction of the FS-12 ETR were trained in accordance with Federal Occupational Safety and Health Administrations (OSHA) regulations. Personnel entering controlled areas were required to have successfully completed 40 hours of hazardous waste instruction offsite, three days of actual field experience under the direct supervision of a trained experienced supervisor, and eight hours of refresher training annually.

Prior to commencement of treatment operations, all site personnel, including visitors and suppliers, who enter controlled areas were required to attend site-specific safety and health training session. These sessions were conducted by site safety personnel to ensure that all personnel were familiar with the requirements and responsibilities of maintaining a safe and healthy work environment.

Periodic onsite safety training was conducted and addressed safety and health procedures, work practices, and changes in work task or schedule, results of previous monitoring, review of safety discrepancies and accidents, and activity hazard analyses.

Medical Surveillance

All personnel working onsite were included in the medical surveillance program. Subcontractor personnel working onsite were required to provide documentation that they participated in a medical surveillance program that complied with state and local regulations. Documentation of current medical surveillance exams were maintained.

The medical surveillance program included scheduling examinations, certification of fitness for duty, compliance with OSHA requirements, and information provided to the physician. The medical surveillance program maintained records of the frequency and content of the examinations.

Personal Protective Equipment (PPE)

The level of PPE was determined by the Program Health and Safety Manager (PHSM). Appropriate levels of protection for each work activity were established by the PHSM based on a review of historical site information, current data, and an evaluation of potential for exposure (inhalation, dermal, ingestion, and injection) for each task. The PHSM was also required to establish action levels for any upgrade or downgrade in levels of PPE. The protocols and communication network for changing the level of protection addressed air monitoring results, potential for exposure, changes in site conditions, work phases, job tasks, weather, temperature extremes, and individual medical considerations.

6.3 Operating Properly and Successfully

AFCEE submitted a letter to the EPA on September 18, 1997 indicating that the FS-12 ETR system was started up on that day. Typically, there is a 30 day period following system startup during which remaining activities (i.e. punchlist items) are completed. Following the 30-day period, the system is considered operating properly and successfully if there are no major system problems.

7.0 OPERATION AND MAINTENANCE (O&M) ACTIVITIES

Long term operations are referred to as O&M while long-term monitoring is referred to as the SPEIM program in this document. O&M activities begin during the system startup and continue throughout the life of the treatment system. SPEIM activities begin prior to system startup with the collection of baseline data. This section discusses both the O&M and SPEIM activities associated with the FS-12 ETR system for the groundwater plume. The O&M and monitoring activities associated with the source area AS/SVE system are detailed in the closure report (AFCEE, March 2000).

7.1 Post-construction O&M

The FS-12 ETR system began operating on 18 Sep 97 and is expected to operate for approximately 15 years post startup. As described previously, the ETR system consists of 23 EWs, 25 RWs, and a treatment plant with an outdoor chemical storage area. The treatment plant houses various unit operations such as influent and effluent equalization tanks, chemical addition, greensand filtration, and granular activated carbon adsorption. The ETR system treats over one million gallons of contaminated groundwater per day, seven days per week.

O&M activities generally include treatment plant monitoring, carbon exchanges, backwashes, well inspection and maintenance, flow rate and pressure monitoring, making appropriate adjustments, and conducting routine/periodic maintenance. These activities are managed by the O&M staff and are described in the following sections.

7.1.1 O&M Personnel and Responsibilities

To ensure attainment of high availability and capacity factors for all the treatment systems at MMR, an operations staff is present ten hours per day, seven days a week. The maintenance staff is present eight hours per day, five days a week. There are six, State of Massachusetts, licensed (certified) wastewater treatment plant operators on staff. In addition to the O&M crews, there is also a Project Manager, Project Engineer, and Plant Superintendent on staff. The following information provides the duties and responsibilities of the personnel. The description of these duties and responsibilities also serves to provide the information regarding the types of O&M activities at the FS-12 and other treatment plants at MMR.

O&M Manager

The O&M Manager is directly responsible for all treatment plant operations and leads the O&M group by organizing, planning, motivating, coordinating and directing the O&M effort. Specific responsibilities include:

- implementation of plans (i.e. quality program plan, health and safety plan, O&M plan);
- management of the O&M effort in accordance with contractual requirements;
- operation of the treatment plants in accordance with all established environmental/clean-up objectives and requirements;
- maintenance of the treatment plants in a manner that exhibits high standards of stewardship for government property and ensures sustained achievement of high availabilities and capacity factors;
- supervision of the O&M staff;
- preparation of all internal and external reports and data records; and,
- communication regarding O&M issues with AFCEE.

O&M Project Engineer

The O&M Project Engineer reports directly to the O&M Manager. The engineer provides technical and management support to the Project Manager and assists the Plant Superintendent with technical matters. Duties include:

- providing technical and staff support to O&M staff;
- operations and plant startup/modifications/expansion support;
- procedure development;
- diagnosing and solving process and equipment problems;
- maintenance of project documents/manuals/record drawings;
- technical liaison between O&M group and technical support groups, e.g., SPEIM staff, engineering staff, drilling/well maintenance staff, and analytical/chemistry staff; and,
- preparing reports and analyzing trends utilizing plant databases.

Plant Superintendent

The plant superintendent reports directly to the O&M manager and has the following responsibilities:

- supervises the O&M staff;
- responsible for the safe, compliant, and efficient operation of all treatment plants;
- hands-on implementation of the plans, project procedures, and plant operations-related requirements of the QPP and HSP;
- management of the plant sampling effort;
- preparation of routine operational reports and notifications;
- management of process residuals (i.e. used GAC) in compliance with all regulatory requirements; and
- managements of assigned government property.

Plant Operators

The Plant Operators report directly to the plant superintendent and are responsible for performing routine plant operations and, when necessary, assist with maintenance activities. Specific responsibilities include:

- control/monitor plant operations;
- perform daily plant walk downs, including visual checks and inspections of facilities and equipment;
- prepare chemical feeds and manage process residuals as required;
- maintain plant logs and prepare routine operating reports;
- collect monthly compliance samples;
- collect routine plant process samples and perform in-house analyses;
- interpret analytical results and make adjustments/corrections as appropriate;
- conduct carbon exchanges as required;
- maintain grounds and facilities;
- assist the maintenance staff as required; and
- conduct plant tours when scheduled.

Maintenance Supervisor

The maintenance supervisor reports directly to the plant superintendent and is responsible for:

- maintenance planning and execution for all treatment plants;
- supervision of the maintenance staff;
- development and implementation of planned/preventative maintenance programs utilizing BenchMate™, the program's Computerized Maintenance Management System (CMMS);
- preparation of work schedules and coordination of maintenance activities with operational requirements;
- development of work methods and maintenance procedures;
- management of the spare parts and tools inventories;
- management of all maintenance contracts, contractors and purchases;
- preparation and closeout of work orders;
- development and implementation of an instrument calibration program; and,
- provide hands-on troubleshooting/maintenance support of control system hardware and software.

Maintenance Technicians

The maintenance technicians report directly to the maintenance supervisor and are responsible for:

- performing all hands-on maintenance activities;
- performing both planned and emergency mechanical and electrical repairs;
- the execution and closeout of work orders;
- calibrating instruments;
- lubricating and adjusting equipment; and
- preparing orders for replacement parts.

All O&M personnel are trained to satisfy all applicable regulatory requirements, observe/implement all applicable site safety and quality standards and procedures, and conduct all job-related responsibilities and functions efficiently and effectively. Training includes initial and refresher training in the following categories:

- OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER);
- Cardiopulmonary Resuscitation (CPR)/first aid fundamentals;
- wastewater treatment plant operator certification,
- orientation for site safety, treatment plant processes, and computer controls;
- confined space entry;
- lock-out/tag-out procedures;
- chemical handling and PPE;
- sampling;
- laboratory analysis and use of test equipment;
- records/reports/administration;
- plant familiarization;
- hands-on operation; and,
- hazardous operations (HAZOP) analysis.

7.1.2 Plant Monitoring and Sampling

Plant monitoring and sampling are conducted at all MMR treatment plants to verify that the plants are operating within design parameters; ensure that the treatment systems achieve compliance with approved design objectives; and, assess if ecological resources are being adversely impacted. The results are reported weekly operations reports and in documents generated under the SPEIM program.

The DQOs for in-plant sampling and monitoring are:

- to determine contaminant concentrations in influent, effluent from the lead GAC vessel, and plant effluent;
- determine when carbon replacement is required,;
- verify that the system provides effluent water that meets the cleanup levels; and
- ensure the treatment system is not adversely affecting nearby ecosystems.

Operational and field sampling parameter samples are analyzed with a field analyzer or a field spectrophotometer kit. Temperature, DO, pH, turbidity, oxidation-reduction potential, and specific conductivity are analyzed by a YSI 6820 or equivalent water quality meter. Iron speciation and manganese concentrations are monitored via a Hach field test kit. A certified laboratory is used to analyze total iron and manganese. Additional information regarding the test procedures and accuracy limits are provided in the *QPP* (AFCEE, September 2000). Plant influent and effluent water samples are analyzed by a certified laboratory for contaminants of concern. Samples are be collected and analyzed per the QPP.

Table 7-1 includes information regarding in-plant monitoring at FS-12. It includes the chemical and field parameters that are measured, the sampling locations, the sampling frequency, and the QA/QC for the sample collection.

7.1.3 Chemical Additions

Plant influent generally has a pH between 5.2 and 6.5 with a low concentration of total suspended solids, iron, manganese, benzene, and EDB. Greensand filters are used to remove suspended solids and iron and manganese to improve the performance of the downstream treatment system. To maximize the removal efficiency of the greensand filters, the pH should be 6.2 or greater. The influent tank pH is adjusted by the addition of 25% sodium hydroxide (NaOH) via a metering pump that transfers the NaOH solution from the chemical storage tank, located outside of the treatment plant building.

Potassium permanganate ($KMnO_4$) is used to regenerate the greensand filters. The $KMnO_4$ demand is dependent upon the concentration of iron and manganese in the influent.

There is a provision to add hydrogen peroxide (H_2O_2) to the effluent in the event the dissolved oxygen concentration is reduced through the treatment process. Through the operational history, it has not been necessary to adjust the dissolved oxygen in the effluent.

There are also provisions to add sodium hypochlorite (NaOCl) as a biocide to control biogrowth and prevent plugging of the reinjection wells.

7.1.4 GAC Change-outs

Most of the treatment plants with the exception of the recirculation wells at SD-5S utilize one or more trains of two, 20,000 pound, GAC vessels. Each "train" consists of two vessels in series. The first vessel, into which groundwater influent is introduced, is the "lead" vessel. The second vessel, which receives effluent from the "lead" vessel, is the "lag" vessel. Repositioning valves to redirect the flow path can change the relative position of each vessel. Within these plants, the GAC media is replaced in the lead carbon vessel when a contaminant is detected in the effluent, referred to as breakthrough, from the lead vessel. If contamination is detected before the projected end of carbon life, a split sample from the lead vessel is analyzed within 24 hours, at the onsite lab to confirm breakthrough.

Immediately following confirmation of a breakthrough condition, a new bed of GAC is ordered to replace the carbon in the lead vessel. The GAC used at MMR is size 12x40 and, based on time-tested experience, it is pH adjusted to prevent a pH spike upon changeout. Generally, the

systems continue to operate without change in configuration until the GAC is replaced. Historical process data indicates the lead GAC vessel has significant adsorptive capacity remaining when breakthrough is detected and the lag vessel is in place as a polishing adsorber. The lag vessel provides effective contaminant removal until the lead GAC vessel's media change out is complete.

Upon changeout, the GAC vessel arrangement is swapped. The vessel with the clean GAC is placed in the lag position and the former lag vessel is placed in the lead position. The GAC replacement cycle is expected to be complete within approximately two weeks after breakthrough has been confirmed for the lead vessel.

The contaminated carbon from the liquid or vapor phase contact systems is transported from the treatment facilities by the carbon supplier in accordance with the terms of their recycling permit. Contaminated carbon typically is recycled through a pyrolytic process that thermally removes and destroys the organic compounds.

The GAC adsorption system at FS-12 was designed to utilize three trains of two 20,000 lb (Figure 7-1). Two trains were always in operation while a third was in standby. When breakthrough occurred in either of the two trains, that train was taken off-line and its flow was diverted to the standby train. The GAC was replaced and the train was placed in standby mode. This operation is still used at the Sandwich Road Treatment Facility where there are four trains; three in operation and one in standby mode.

In July 1999, a GAC reconfiguration project was completed at FS-12 to better utilize the GAC. The FS-12 plant still utilizes the conventional two GAC vessel train, however, its three trains are now uniquely operated to optimize their adsorption of contaminants, specifically EDB (Figure 7-2). The first two trains are operated in parallel (influent flow is split equally between the two trains), and effluent from the two parallel trains is combined and is directed through the third train. This effectively provides a process depth of three or four carbon vessels, depending upon how the final third or polishing train is configured. This allows the "lead" vessels in the parallel trains to be operated beyond their point of breakthrough, thus increasing their loading potential for contaminants. With this configuration, immediately following confirmation of a breakthrough condition from a "lag" vessel, in the lead train, a new bed of GAC is ordered to replace the carbon in the "lead" vessel of that same train. The system continues to operate without change in configuration until the GAC is replaced. The third train provides effective contaminant removal until the lead carbon vessel's media change out is complete. The new GAC is placed in the lag position and the former lag carbon vessel is placed in the lead position (AFCEE, January 2001).

Prior to the GAC reconfiguration project, FS-12 experienced 15 GAC changeouts from system startup in September 1997 through July 1999 due to detection of COCs in the post-lead GAC vessels. This represented a total carbon consumption of 300,000 pounds and a cost of $255,000 ($0.85 per pound). The corresponding mass of EDB captured with this amount of carbon was 94 pounds, which relates to and EDB loading rate of approximately 3.13×10^{-4} pounds of EDB per pound of GAC. This is substantially below the capacity predicted by isothermal data. Following the reconfiguration project in July 1999, four GAC changeouts have been conducted to date (January 2001). This represents a substantial cost savings, based on $0.85 per pound of GAC, in addition to ensuring that the last vessel remains uncontaminated.

7.1.5 GAC and Greensand Filter Backwashes

In order to ensure the most efficient use of the greensands filters and GAC vessels, they must be backwashed to remove entrained solids. Backwash water and filtered solids (sludge) are collected in backwash/sedimentation tanks. The solids are allowed to settle to the bottom of the tank and the supernatant is decanted and processed through the treatment plant. Periodically, solids that have accumulated in the bottom of the tank(s) are disposed off-site. A subcontractor

transfers the sludge from the tank to a Vac truck, and transports it to a permitted wastewater treatment plant.

There are four greensand filters at FS-12. Current operation requires a backwash on a rotating daily schedule. That is, each greensand filter is backwashed once every four days as a result of operational history. Initially, the greensands were backwashed when the differential pressure reached 7 pounds per square inch (psi). However, over time, the filters became clogged with solids and eventually had to be changed out. An effective means of efficiently maintaining the filters is to conduct frequent backwashes. A backwash takes approximately 15 to 20 minutes at 1000 gpm.

The carbon vessels at FS-12 are backwashed when the differential pressure readings reach 10 psi. This occurs approximately every three to four weeks. An effective backwash will reduce the differential pressure reading to approximately 3-4 psi.

7.1.6 Pipeline Leak Detection Monitoring and Pressure Testing

Leak detection monitoring is provided by several different means that, in general, have a level of protection that is commensurate with the level of risk associated with a potential leak. In several of the treatment systems, including FS-12, the extraction headers utilize double wall pipe. The annular space between the influent pipe and the "guard" pipe (secondary containment) is vented/drained to the well vaults and plants proper to provide a means to detect and contain potential leakage. The extraction well vaults and the treatment building are designed to provide secondary containment in the event of a leak. In the event of a leak from the process pipe to the guard pipe, the annular space will fill with water until it overflows into a well vault or into the plant, where it will be contained and detected by a level sensor. Each extraction well vault and treatment building is provided with a float switch. Upon detection of a high level by an extraction well vault level switch, the affected treatment facility and all influent well pumps are programmed to shut down. Upon detection of a high level by the treatment building sump level switch, the sump pump will begin to operate. The sump pump will stop when the level switch detects a low level. If the sump pump continues to operate beyond a specified time limit or indicates repeated operation in a specified time period, the affected treatment facility will shut down.

The integrity of the "guard" pipe to contain leakage is checked annually by temporarily blocking the vents/drains within the vaults and building(s) and pressure testing the pipe in accordance with its original pressure test specification. Pressure testing at FS-12 was last conducted on September 28, 2000 and is now on a yearly schedule with the next test to occur around September 2001.

7.1.7 Well Inspection and Maintenance

The combined treatment capacity of all MMR treatment plants is approximately 12 million gallons per day. To ensure optimal contaminant capture, minimal impact on the environment, and operational longevity, it is essential that each of the approximately one hundred extraction and reinjection wells operate as designed. Well performance is consistently monitored and any deficiencies corrected. A well inspection and maintenance plan has been established to proactively monitor well performance and build an information database that can be used to schedule and predict the need for preventative well maintenance, i.e., refurbishment.

At FS-12, several of the extraction wells and reinjection wells have been inspected and maintained. Results of these inspections have indicated the need for routine maintenance at some of the EWs.

The design flow rates for each extraction and reinjection well are shown in Table 7-2. As a result of recent events regarding detections of EDB in zones outside of the FS-12 plume, modifications

have been made to the extraction and reinjection rates of some wells. Notes provided in Table 7-2 explain the discrepancies between the design flow rates and the operational flow rates.

Outside of the voluntary changes in flow rates, there are cases in which the flow rates begin to decrease (i.e. due to biofouling) over time. The well and pump inspection/maintenance program will provide the data necessary to track declining performance trends. Well and pump performance thresholds have been established to schedule well and/or pump maintenance activities before impacting plume capture. These performance thresholds will be used to assure that the wells and pumps continue to operate in accordance with the well field performance design criteria. Threshold levels are expressed as a percentage of decline from the original performance standard. The pump performance threshold is measured as a decline in total dynamic head produced at a given flow as depicted on the manufacturer's pump curve. The well performance is measured as a decline in specific capacity from the original level when the well was constructed. The maintenance thresholds are provided in Table 7-3a for the pump performance and in Table 7-3b for the EW performance.

The reinjection well inspection procedure includes testing and analysis of the hydraulic characteristics of the reinjection well performance. Water level data will be evaluated to determine the change in groundwater level (i.e., mounding) within the well screen during reinjection well use. Results of the inspection will be used to schedule routine well maintenance. The inspection will include the following:

- Cleaning the flow element located at the reinjection well vault.
- Documentation of control valve position and injection flow rate.
- Measurement of water levels for static and injection conditions
- Comparison of groundwater level changes during injection (where available) and pumping to original values.

The following operating procedures are considered in order to maximize capture efficiency when the treatment plant goes down or a well or a number of wells are not working properly:

- If the system is down less than 48 hours, restart the system at design rates.
- If the system is down 2-10 days, each well in the wellfield should be operated at 10% above the design flow rate for the number of days that the system was down. If plant capacity does not allow an additional 10% throughput, the southern toe fence wells should be operated 10% above design rates.
- If individual extraction wells in the southern toe fence experience or are projected to experience no flow conditions for periods longer than 48 hours, the adjacent wells should operate at rates that will make up the shortfall plus 20%.
- If individual extraction wells in the southern toe fence experience low flow conditions (flow rates 10% less than design rates) for periods longer than 72 hours, the adjacent wells should operate at rates that will make up the shortfall plus 20%.
- If individual axial wells experience low flow (more than 15% below design rates) or no flow conditions for periods longer than 72 hours, the shortfall should be made up in the other axial wells.
- If the system is down longer than 10 days, the wells in the well field should be run at their maximum capacities and/or capacity of the plant.
- If the plant experiences (planned or unanticipated) reduced flows (10% below the full system design rate) for periods longer than 72 hours, operate the southern toe extraction fence at full design rates and reduce the axial fence accordingly.
- If the plant experiences (planned or unanticipated) reduced flows below the combined flow rate for the southern toe fence wells for periods longer than 72 hours, operate wells 22

through 28 at design rates and reduce the extraction rates in the remaining toe wells accordingly.

- During low or high total system flow conditions, evenly distribute the treated water to the reinjection wells.

7.2 Monitoring Program

SPEIM activities, as the name implies, include both system performance and ecological impact monitoring. System performance monitoring refers to the performance evaluation of the groundwater treatment systems. This is accomplished by routinely measuring groundwater levels (i.e. hydraulic analyses) and chemistry via a network of monitoring wells. The numbers, locations, and depths of the monitoring wells are selected to allow for the efficient and timely detection of any significant changes in indicator parameters. Ecological monitoring refers to collecting and analyzing hydrological, surface water, and sediment and biological data to monitor whether the treatment systems affect an ecological resource. These activities are managed by the SPEIM group

7.3 Future Groundwater Restoration Activities

Future groundwater restoration activities at FS-12 include continued monitoring, optimizing the monitoring well network, optimizing the flow rates from the extraction wells, and remapping the plume as it is remediated. This work will continue until cleanup goals are met. These goals will be better defined through the IROD to ROD process in which AFCEE is currently in discussion with the regulators.

One additional groundwater restoration activity is described in Section 2.3.2 and involves a modification to the existing FS-12 ETR system.

8.0 Summary of Project Costs

This section primarily discusses the costs associated with the FS-12 groundwater plume remediation project and, to a limited extent, the FS-12 source area. Estimated costs are compared with actual costs for the FS-12 groundwater plume ETR system and explanations related to the major cost drivers are included.

8.1 FS-12 Source Area

8.1.1 Projected Costs

An estimated cost range for the removal action at the source area was reported as $2,000,000 to $3,000,000 (AFCEE, November 1996).

8.1.2 Actual Costs

The cost for the source area AS/SVE remedial action was approximately $3,700,746, which included preparation of the Action Memorandum (approximately $25k), the remedial design ($1.5 million), and the construction ($2,175,746). This is comparable to the estimate provided in Section 8.1.1.

8.2 FS-12 Groundwater Plume

8.2.1 Projected Costs

Two alternatives were provided in the IROD for addressing seven groundwater plumes, including FS-12: (1) No Action Alternative and (2) Plume Containment Alternative. Costs includes the capital (i.e. equipment and installation) of implementing a remedial action, as well as the O&M costs. The estimated total present worth (based on 1994 dollars) cost considered both the capital and O&M. The net present worth cost (1994 dollars) for the no-action alternative was estimated to be $6,018,700, based on 20 years of operation. The net present worth (1994 dollars) cost for the plume containment alternative was estimated to be $179,352,000, based on 20 years of operation.

These costs were based on the remedial alternatives for seven groundwater plumes. In order to extrapolate the costs for one plume (FS-12), the costs for the No Action Alternative were divided by seven. The Plume Containment Alternative considered the pumping rate for seven plumes to be 11 million gallons per day. The FS-12 ETR design pumping rate is 1.14 million gallons per day, which represents approximately 10.4% of the pumping rate for the seven plumes. Thus, the costs associated with the FS-12 treatment are estimated to be 10.4% of the total cost estimated for the Plume Containment Alternative. The following table provides pertinent information in developing the preliminary cost estimates as well as estimated costs for these two alternatives, along with the extrapolated costs for FS-12.

Category	No Action Alternative	Plume Containment Alternative	Extrapolated FS-12 Alternative
Estimated time for design and construction	None	42 months	NA
Estimated time of operation	20 years	20 years	20 years
Estimated capital costs (1997)	None	$112,755,000[1]	$11,726,520[1]
Estimated O&M costs (1994)	$482,900	$66,597,000[2]	$6,926,088[2]
Adjusted O&M costs (2000)[3]	$647,086	$89,239,980	$9,280,958
Estimated total cost (1994)	$6,018,700	$179,352,000	$18,652,608
Adjusted total cost (2000)[3]	$8,065,058	$240,331,680	$24,994,495

[1] Includes equipment and installation (1997 dollars)
[2] Total O&M cost for 20 years
[3] Costs calculated using 5% interest over 6 years with an index of 1.34.

8.2.2 Actual Costs

The cost for the construction of the FS-12 groundwater ETR was $24,318,243 and is subdivided according to the following table:

CATEGORY	COST ($)
Preconstruction Plans	55,970
Engineering	2,121,180
Groundwater Piping/Controls	5,591,263
Treatment Building/System	7,391,644
Drilling	5,136,534
Sampling	648,126
Modeling	741,887
Startup	455,001
Operation and Maintenance	242,747
Project Management	1,933,891
TOTAL	24,318,243

The estimated capital cost of $11,726,520 included equipment and installation. The actual capital cost of equipment and installation was approximately $18,574,442, a variation of +37%.

The following table provides cost by fiscal year (FY) for various activities at FS-12 since system startup. To date, $33,728,715 has been spent on FS-12. These costs do not include those for community involvement activities, residential sampling, water hookups, the FS-12 Phase II Investigation, database management, or planned system modifications. Costs for the FS-12 Phase II investigation were approximately $1,148,700 and costs for water hookups total $932,354.

ACTIVITY	FY96/97 ($)	FY98 ($)	FY99 ($)	FY00 ($)	TOTAL
Construction	24,318,243				24,318,243
Ecological Program	2,240,829	1,028,221	248,378		3,517,428
O&M		1,569,861	933,566	797,792	3,301,219
Performance Monitoring		480,525	422,271		903,246
SPEIM				1,201,455	1,201,455
GAC*				$35,800	$35,800
Electricity	20,519	151,595	133,210	146,000	451,324
TOTAL	26,579,591	3,230,202	1,737,875	2,181,047	33,728,715

* previously included with O&M

Eventually, O&M costs should begin to stabilize. The following table provides a breakdown of expected annual O&M costs for FS-12.

O&M CATEGORY	COST ($)
Personnel, tools, equipment, vehicles	460,000
Sampling, chemistry, data management	110,000
Spare parts	94,000
Sludge disposal	34,000
Well maintenance	97,000
Carbon exchanges	96,000
Electricity	140,000
TOTAL	1,031,000

Since startup through December, 2000, the FS-12 ETR system has removed 71.7 pounds of benzene and 120.4 pounds of EDB for a total of 192.1 pounds of COCs. This is approximately $175,600 per pound, or $11,000 per ounce, of contaminant removed.

The matrix characteristics and site conditions that most affect the costs reported in this section include a sandy, homogenous aquifer with high hydraulic conductivity, relatively low concentrations of contaminant mass in the volume of the plume, site conditions, and long-term restoration plans. Because the aquifer is highly conductive, the extraction system must be designed to capture a larger area. This is comparable to adding a safety factor into the design. The large capture area tends to dilute the contaminants, which makes the treatment system less efficient. The ETR system at FS-12 was built in an undeveloped area (i.e. many trees, no roads) which resulted in high infrastructure costs. In addition the extracted groundwater is piped through double-walled pipe for containment in the event of a leak. The ETR was also designed to operate continuously, 24 hours per day, seven days per week, for a maximum life of 30 years.

Additional costs associated with remedial activities at FS-12 include an estimated cost of $749,530 for the remedial design (RD) and RA of the temporary ETR modification for the capture and treatment of the EDB zones discovered under Snake Pond outside of the main FS-12 plume. The details of the ETR modification are described in Section 2.3.2.

9.0 OBSERVATIONS AND LESSONS LEARNED

Groundwater modeling was utilized as one of the primary tools in developing the FS-12 ETR groundwater remediation system. It was recognized early on in the process that all modeling efforts contain some uncertainty. Additional data collection prior to system startup, allowing for flexibility in the system (designing for a range of COC concentrations), and designing in safety factors (i.e. oversizing tanks) can help to better manage the uncertainties. Follow on data collection and model recalibration efforts based on actual data is another tool used in managing uncertainties.

A UV/OX system was designed into the system and the equipment was installed in the FS-12 treatment plant. However, within a few short weeks after startup, it was determined that the UV/OX was not necessary as the organic contaminant concentration was lower than anticipated, obviating the need for this treatment.

Part of the UV/OX system (the oxidation part) included provisions to add hydrogen peroxide to the effluent to increase the DO concentration. However, it was decided this was not necessary as the DO concentration in the effluent fell within acceptable limits.

Reconfiguration of the GAC vessel layout is described in Section 7.1.4. Due to the enormous success of this project, a similar reconfiguration was planned for another treatment plant which treats chlorinated solvents. Research into the physicochemical properties of one of the compounds (cis-1,2-dichloroethene), however, determined that the reconfiguration may not be suited for all contaminants. The adsorptive capacity of GAC for cis-1,2-dichloroethene is much less than that for EDB and there is little accumulation of this compound on the GAC.

10.0 OPERABLE UNIT CONTACT INFORMATION

Contact information is provided in Table 10-1.

APPENDIX A. FIGURES AND TABLES

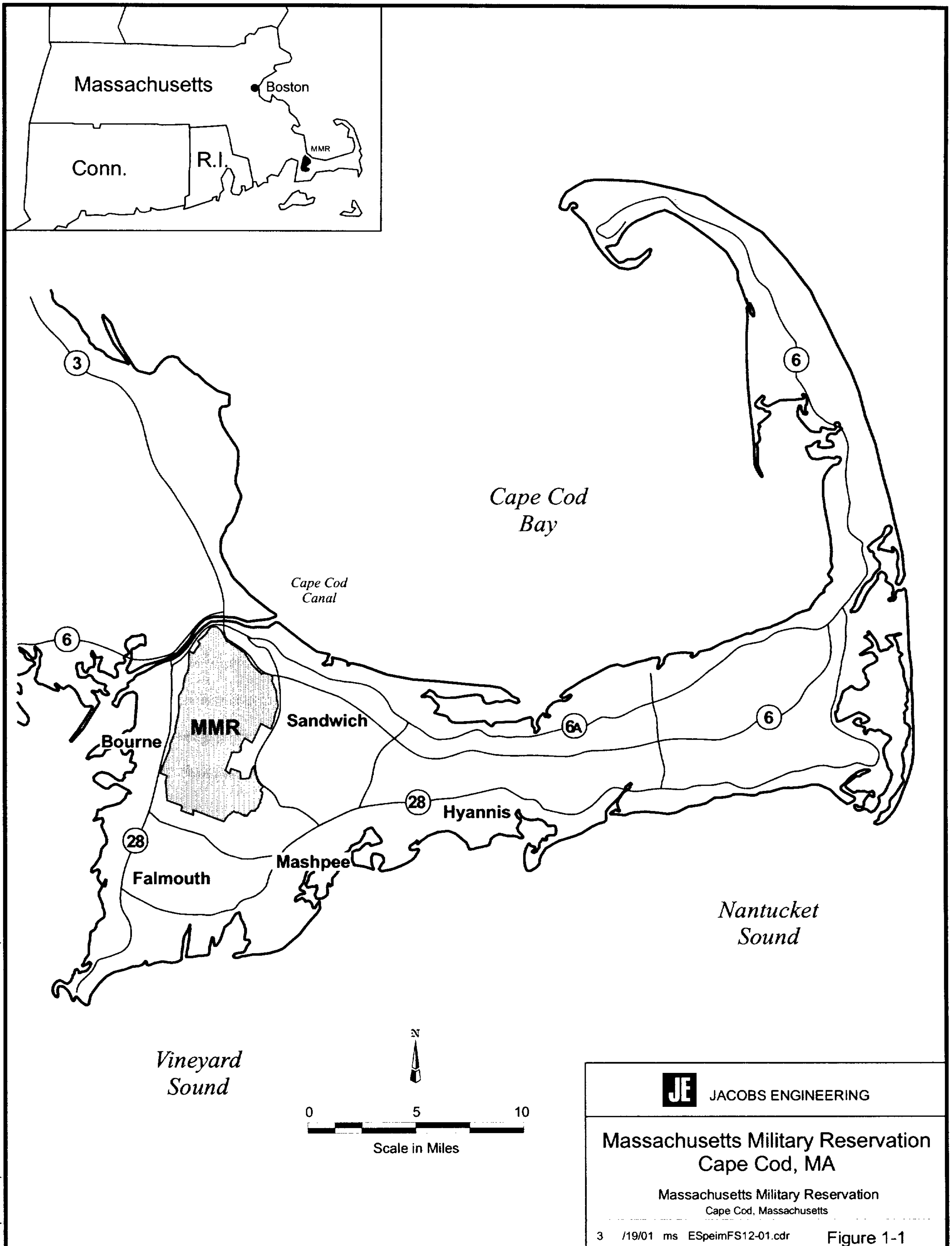

Figure 1-1

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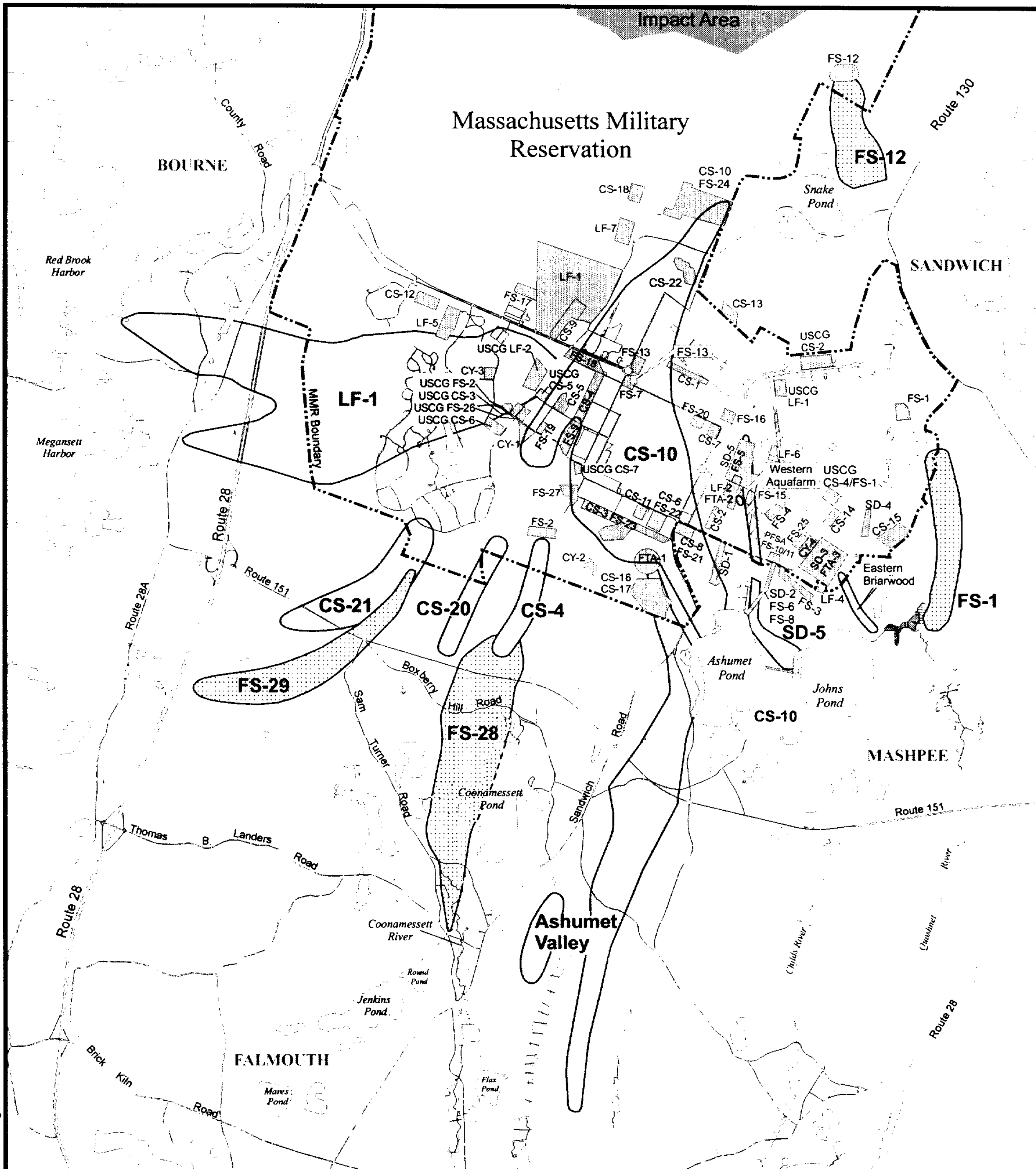

Legend

Plume Contour (TCE, PCE MCL = 5 μg/L)

Plume Contour (EDB MCL = 0.02 μg/L)

Source Area

0 3000
Scale in Feet

Note: Northern Source Areas CS-19, FS-14, LF-3, USCG/LF-3, USCG/CS-1 are not shown.

JACOBS ENGINEERING

Plume and Source Area Map
January, 2000

Massachusetts Military Reservation
Cape Cod, Massachusetts

03/19/01 ms File:..ESpeimFS12-11.cdr

Figure 1-2

Q:\Graphics1\Reports\0-REPORTS-99\LF-1\Modeling000\Corel\PL00allScBW.cdr

Legend

MMR Boundary

Plume Contour: (EDB MCL = 0.02 μg/L)

N

0 3000

Scale in Feet

JACOBS ENGINEERING

FS-12 Plume
Site Location Map

Massachusetts Military Reservation
Cape Cod, Massachusetts

04/11/01 SC ESpeimFS12-12.dwg

Figure 1-3

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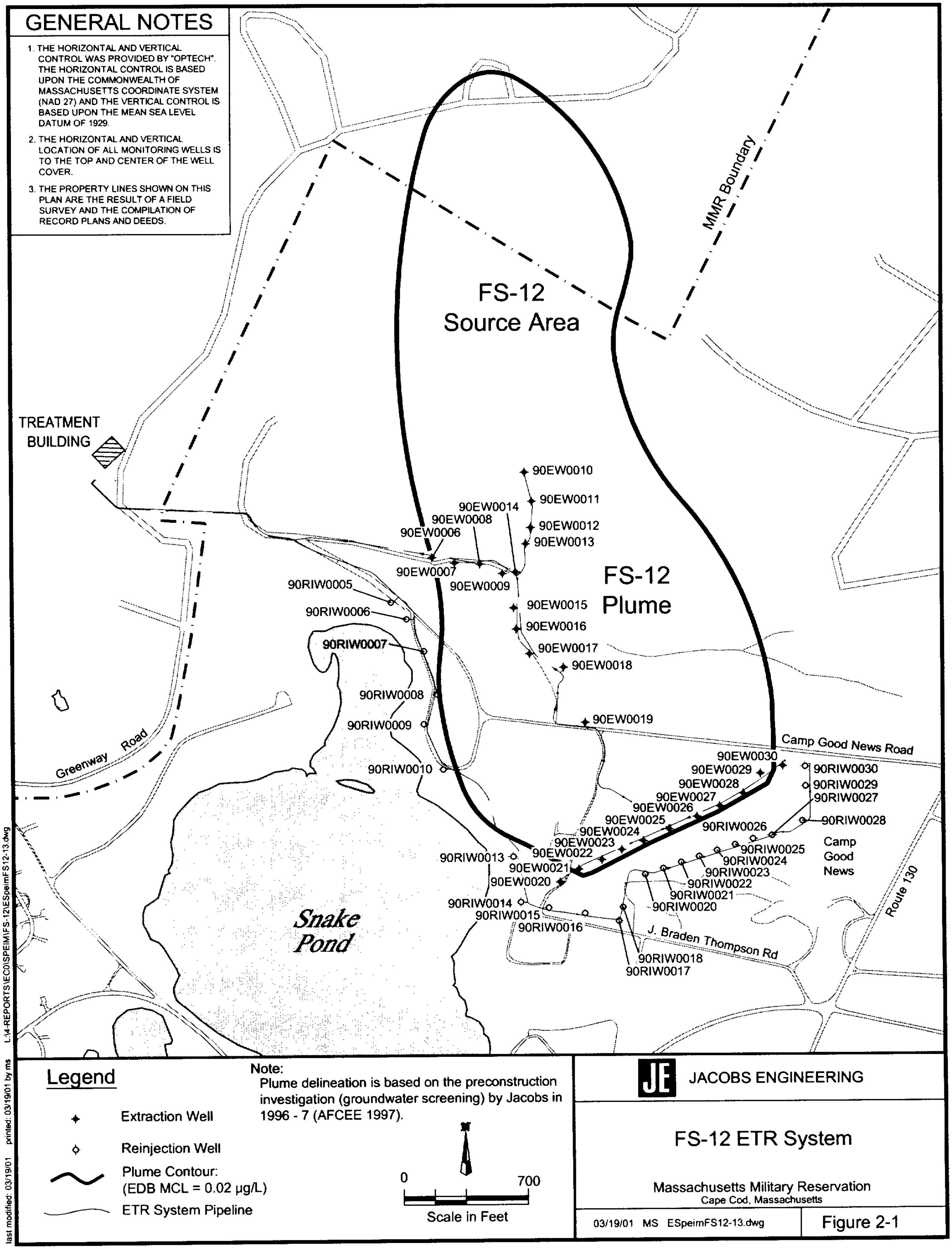
GENERAL NOTES
1. THE HORIZONTAL AND VERTICAL CONTROL WAS PROVIDED BY "OPTECH". THE HORIZONTAL CONTROL IS BASED UPON THE COMMONWEALTH OF MASSACHUSETTS COORDINATE SYSTEM (NAD 27) AND THE VERTICAL CONTROL IS BASED UPON THE MEAN SEA LEVEL DATUM OF 1929.
2. THE HORIZONTAL AND VERTICAL LOCATION OF ALL MONITORING WELLS IS TO THE TOP AND CENTER OF THE WELL COVER.
3. THE PROPERTY LINES SHOWN ON THIS PLAN ARE THE RESULT OF A FIELD SURVEY AND THE COMPILATION OF RECORD PLANS AND DEEDS.
MMR Boundary
FS-12
Source Area
TREATMENT
BUILDING
90EW0010
90EW0011
90EW0014
90EW0008
90EW0012
90EW0006
90EW0013
90EW0007
90EW0009
FS-12
Plume
90RIW0005
90RIW0006
90EW0015
90EW0016
90RIW0007
90EW0017
90EW0018
90RIW0008
90EW0019
90RIW0009
Greenway Road
Camp Good News Road
90EW0030
90EW0029
90RIW0030
90RIW0010
90EW0028
90RIW0029
90EW0027
90RIW0027
90EW0026
90EW0025
90RIW0028
90EW0024
90RIW0026
90EW0023
90RIW0025
Camp
Good
News
90RIW0013
90EW0022
90RIW0024
90EW0021
90RIW0023
90EW0020
90RIW0022
90RIW0021
Route 130
90RIW0014
90RIW0020
90RIW0015
Snake
Pond
90RIW0016
J. Braden Thompson Rd
90RIW0018
90RIW0017
Legend
Extraction Well
Reinjection Well
Plume Contour:
(EDB MCL = 0.02 μg/L)
ETR System Pipeline
Note:
Plume delineation is based on the preconstruction investigation (groundwater screening) by Jacobs in 1996 - 7 (AFCEE 1997).
0
700
Scale in Feet
JE
JACOBS ENGINEERING
FS-12 ETR System
Massachusetts Military Reservation
Cape Cod, Massachusetts
03/19/01 MS ESpeimFS12-13.dwg
Figure 2-1
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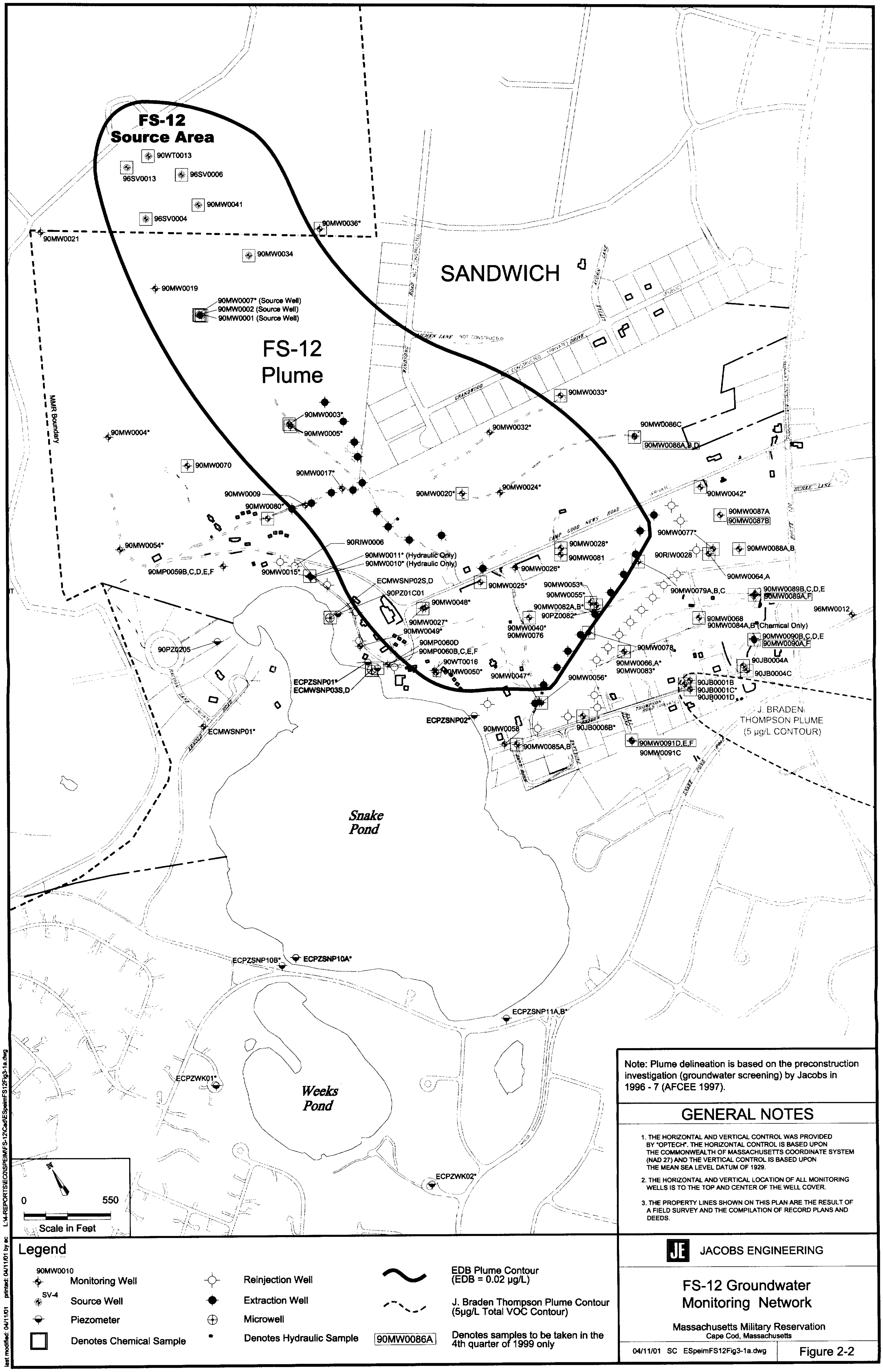
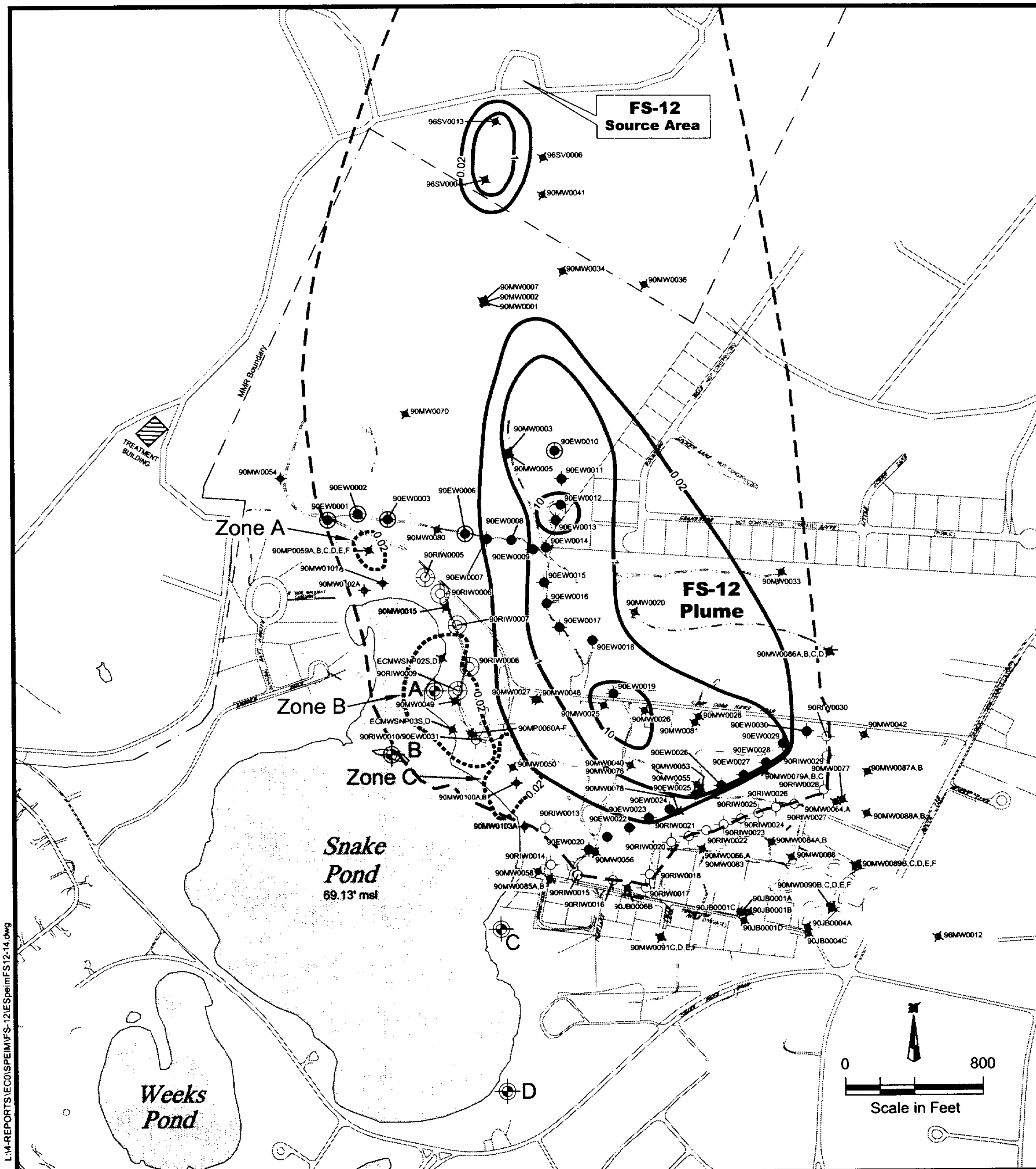
last modified: 03/19/01 printed: 03/19/01 by ms


FS-12
Source Area
90WT0013
96SV0013
96SV0006
90MW0041
96SV0004
90MW0036*
90MW0021
90MW0034
90MW0019
90MW0007* (Source Well)
90MW0002 (Source Well)
90MW0001 (Source Well)
SANDWICH
FS-12
Plume
MMR Boundary
90MW0003*
90MW0005*
90MW0004*
90MW0070
90MW0017*
90MW0009
90MW0080*
90MW0054*
90MP0059B,C,D,E,F
90MW0015*
90RIW0006
90MW0011* (Hydraulic Only)
90MW0010* (Hydraulic Only)
ECMWSNP02S,D
90PZ01C01
90MW0033*
90MW0032*
90MW0086C
90MW0086A,B,D
90MW0020*
90MW0024*
90MW0042*
90MW0087A
90MW0087B
90MW0077*
90MW0028*
90MW0081
90RIW0028
90MW0088A,B
90MW0064,A
90MW0026*
90MW0025*
90MW0053*
90MW0055*
90MW0079A,B,C
90MW0089B,C,D,E
90MW0089A,F
96MW0012
90MW0048*
90MW0082A,B*
90PZ0082*
90MW0068
90MW0084A,B (Chemical Only)
90MW0027*
90MW0049*
90MW0040*
90MW0076
90MP0060D
90MP0060B,C,E,F
90MW0078
90MW0090B,C,D,E
90MW0090A,F
90WT0016
90MW0050*
90MW0066,A*
90MW0083*
90JB0004A
90JB0004C
90PZ0205
ECPZSNP01*
ECMWSNP03S,D
90MW0047*
90MW0056*
90JB0001B
90JB0001C*
90JB0001D
J. BRADEN
THOMPSON PLUME
(5 µg/L CONTOUR)
ECPZSNP02*
90MW0058
90JB0006B*
90MW0085A,B
90MW0091D,E,F
90MW0091C
ECMWSNP01*
Snake Pond
ECPZSNP10B*
ECPZSNP10A*
ECPZSNP11A,B*
ECPZWK01*
Weeks Pond
ECPZWK02*
0
550
Scale in Feet
Note: Plume delineation is based on the preconstruction investigation (groundwater screening) by Jacobs in 1996 - 7 (AFCEE 1997).
GENERAL NOTES
1. THE HORIZONTAL AND VERTICAL CONTROL WAS PROVIDED BY "OPTECH". THE HORIZONTAL CONTROL IS BASED UPON THE COMMONWEALTH OF MASSACHUSETTS COORDINATE SYSTEM (NAD 27) AND THE VERTICAL CONTROL IS BASED UPON THE MEAN SEA LEVEL DATUM OF 1929.
2. THE HORIZONTAL AND VERTICAL LOCATION OF ALL MONITORING WELLS IS TO THE TOP AND CENTER OF THE WELL COVER.
3. THE PROPERTY LINES SHOWN ON THIS PLAN ARE THE RESULT OF A FIELD SURVEY AND THE COMPILATION OF RECORD PLANS AND DEEDS.
Legend
90MW0010
Monitoring Well
SV-4
Source Well
Piezometer
Denotes Chemical Sample
Reinjection Well
Extraction Well
Microwell
Denotes Hydraulic Sample
EDB Plume Contour
(EDB = 0.02 µg/L)
J. Braden Thompson Plume Contour
(5µg/L Total VOC Contour)
90MW0086A
Denotes samples to be taken in the 4th quarter of 1999 only
JE
JACOBS ENGINEERING
FS-12 Groundwater
Monitoring Network
Massachusetts Military Reservation
Cape Cod, Massachusetts
04/11/01 SC ESpeimFS12Fig3-1a.dwg
Figure 2-2



Note: Plume contour from 2000 data.

Legend

- Extraction Well (operable)
- Extraction Well (non-operable)
- Reinjection Well (operable)
- Reinjection Well (non-operable)
- D Proposed Monitoring Well
- FS-12 EDB Plume Contour (EDB MCL = 0.02 µg/L)
- Capture Zone
- Piezometer
- Monitoring Well

JACOBS ENGINEERING

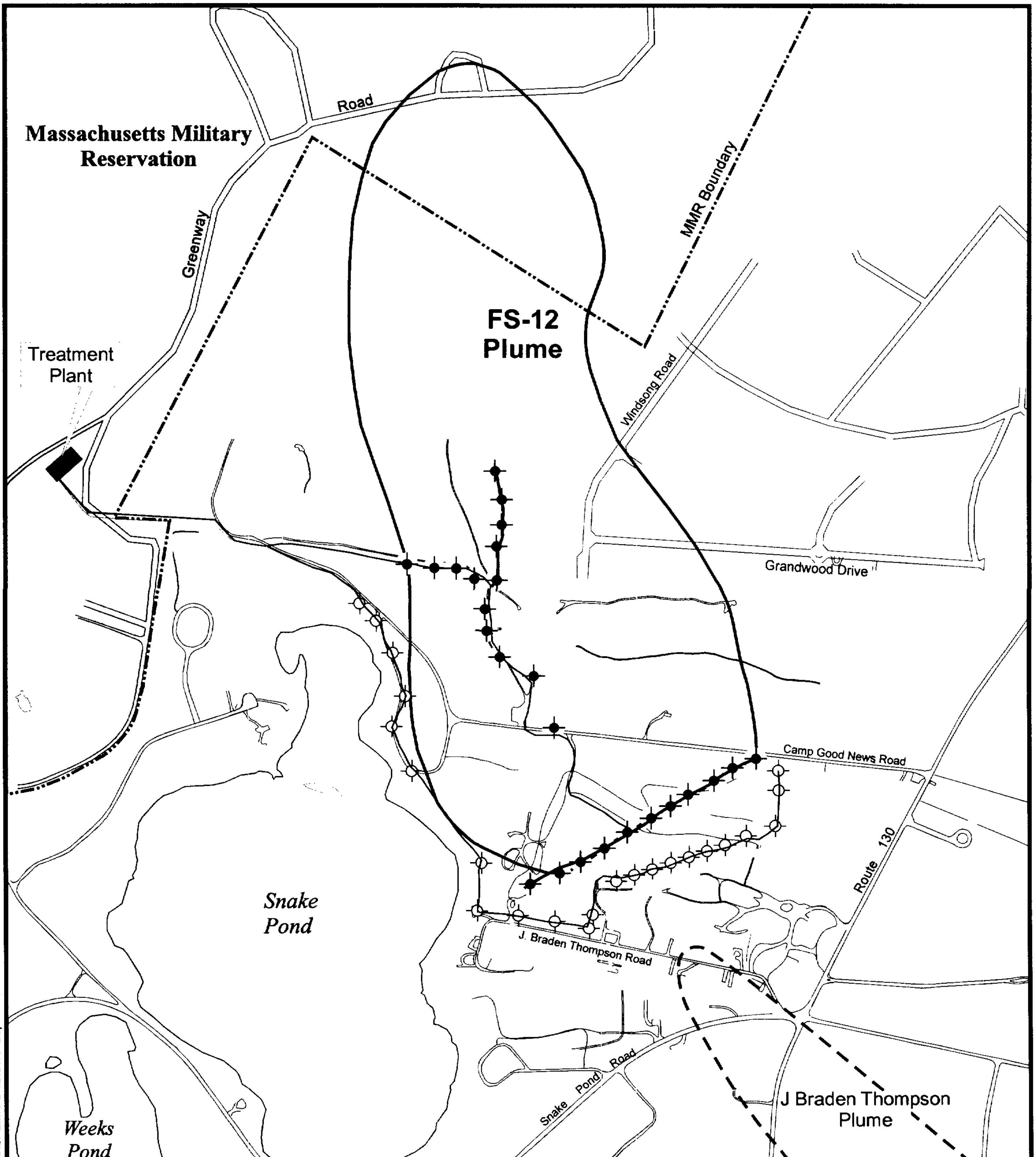
FS-12 Plume and EDB Zones (2000)

Massachusetts Military Reservation
Cape Cod, Massachusetts

03/19/01 MS ESpeimFS12-14.dwg

Figure 2-3

last modified: 03/19/01 printed: 03/19/01 by ms L:\14-REPORTS\EC0\SPEIM\FS-12\ESpeimFS12-14.dwg



Legend

- Extraction Well
- Reinjection Well
- Treatment System Piping
- Plume Contour (EDB MCL = 0.02 μg/L)
- J. Braden Thompson Plume
- MMR Boundary

0 750
Scale in Feet

Note:
Plume delineation is based on the preconstruction investigation (groundwater screening) by Jacobs in 1996-7 (AFCEE 1997).

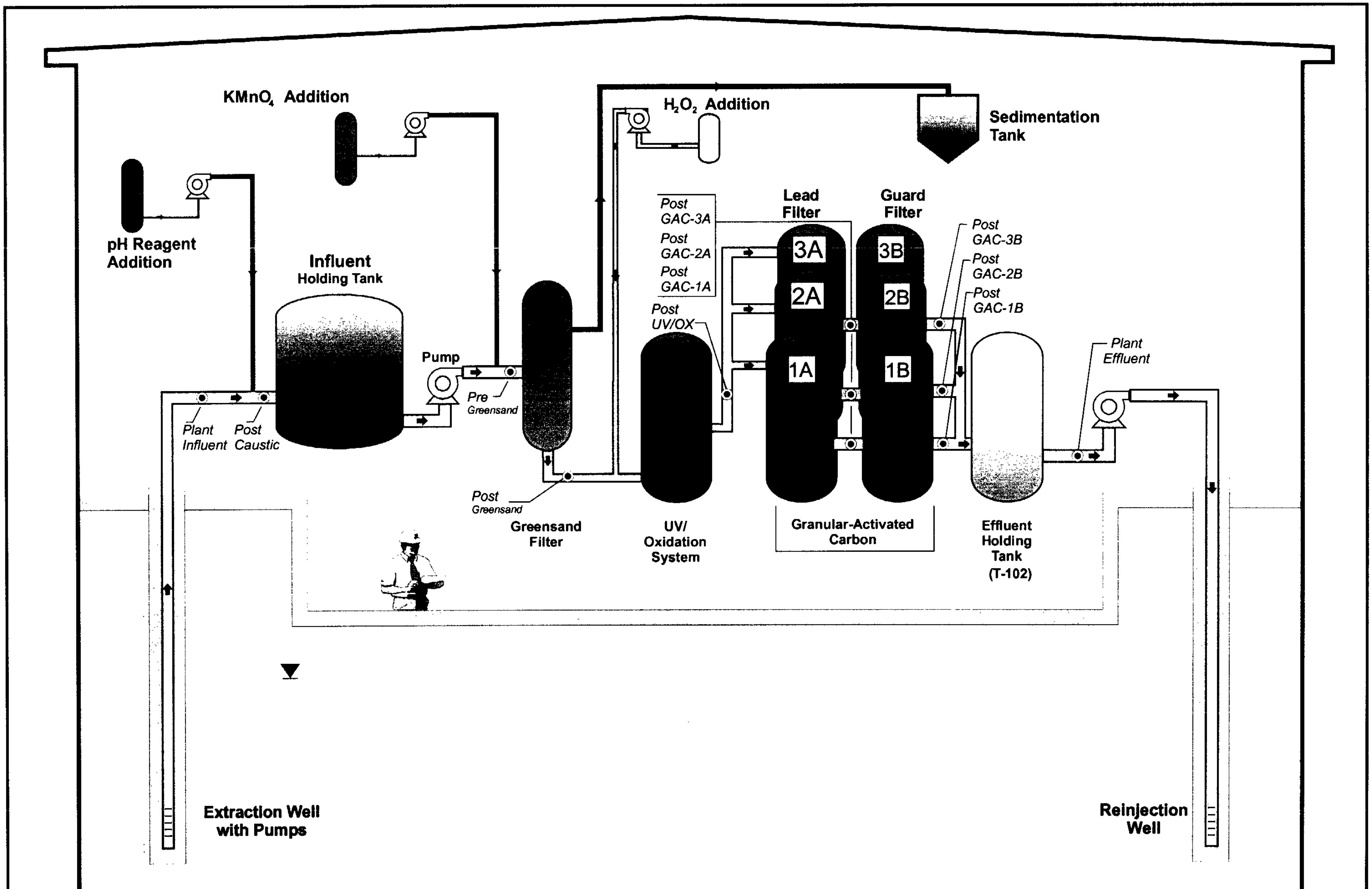
JACOBS ENGINEERING

FS-12 Plume Area Map
Basis of Design

Massachusetts Military Reservation
Cape Cod, Massachusetts

3/19/01 ms ESpeimFS12-03.cdr

Figure 5-1



Legend

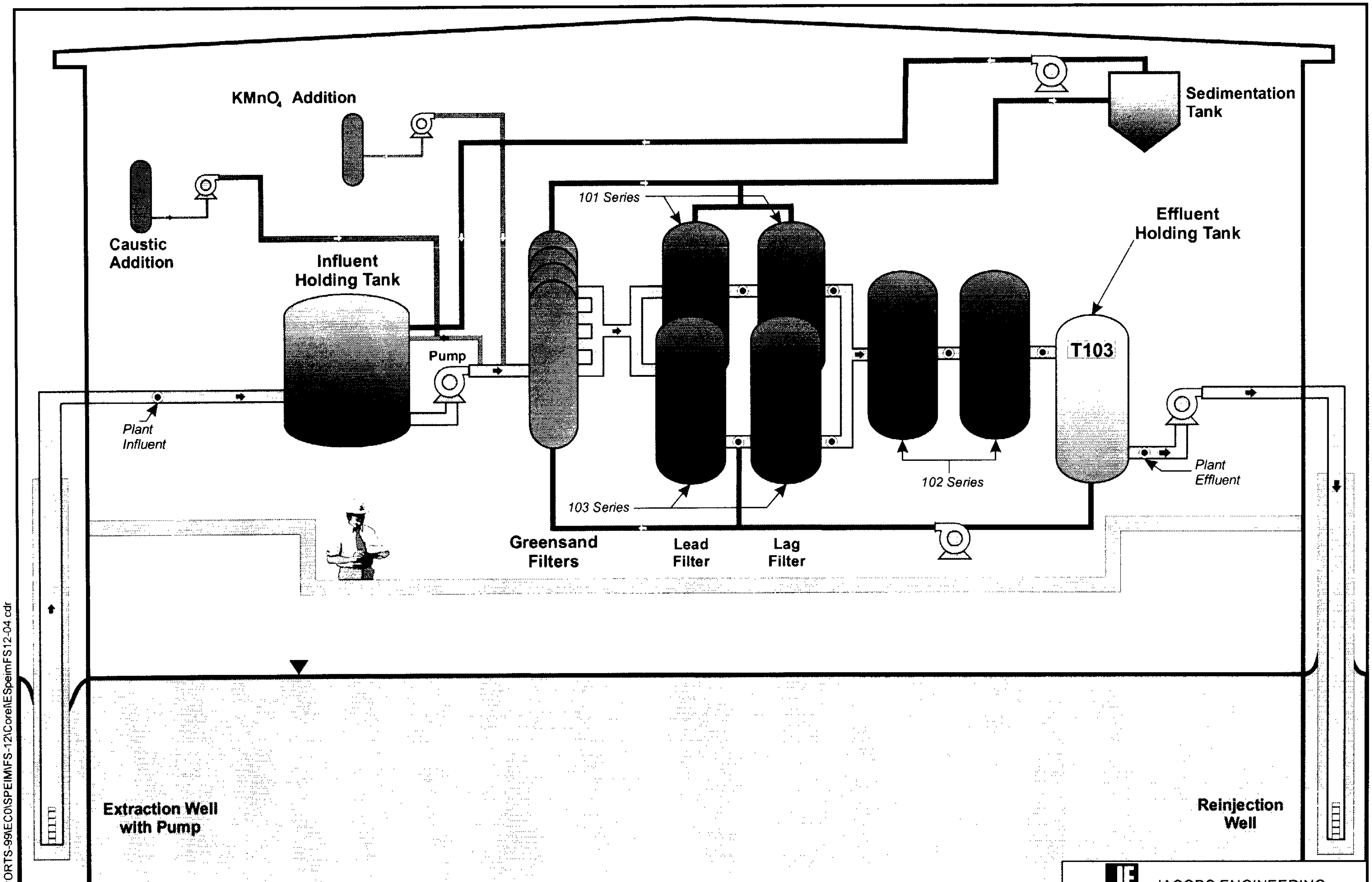
•	Sample Port
$KMnO_4$	Potassium Permanganate
H_2O_2	Hydrogen Peroxide

JE JACOBS ENGINEERING

Process Flow Diagram with Sample Locations at the FS-12 ETR System

4/11/01 sc File:..Fs12flo5.cdr

Figure 7-1



Legend

•	Sampling Port	$KMnO_4$	Potassium Permanganate
▼	Water Table		

JACOBS ENGINEERING

Reconfigured Process Flow Diagram at the FS-12 ETR System with Sampling Locations
Massachusetts Military Reservation
Cape Cod, Massachusetts

3/19/01 ms ESpeimFS12-04.cdr | Figure 7-2

Q:\Graphics1\Reports\0-REPORTS-99\EC0\SPEIM\FS-12\Corel\ESpeimFS12-04.cdr

TABLE 3-1. FS-12 ETR CONSTRUCTION ACTIVITIES

TIMEFRAME	ACTIVITIES
From contract award through 23 Aug 96	Selected site for treatment facility at intersection of Old Greenway Road and New Greenway Road
Through 27 Sep 96	Submitted Draft Project Execution Plan on September 9, 1996
	Negotiated access agreements for installing the wells, pipeline and electrical lines on private property
Through 01 Nov 96	Submitted Draft Design report on October 21, 1996
	Held discussions with regulatory agencies on groundwater modeling efforts and ETR impact on nearby J.B. Thompson plume
	Finalized access agreements
	Began installation of data gap monitoring wells for plume delineation
	Began installation of borings at EW and RW locations to confirm lithology and depth of plume
	Conducted public meetings for informational purposes
Through 29 Nov 96	Continued installing data gap wells for plume delineation and borings at EW and RW locations
	Installed 4 RWs and began installation of one EW
	Awarded subcontracts for the treatment building and related civil/structural/architectural activities
	Prepared undeveloped areas for access (i.e. cleared and built roads in the area of RWs 14 through 17)
	Let purchase requisitions for all long lead items
Through 3 Jan 97	Completed installation of data gap wells and borings at EW and RW locations
	Completed installation of 10 RW/EWs
	Began cut and fill operations for civil preparation work for the treatment building
	Completed investigative derived materials system for handle water generated on-site
Through 31 Jan 97	Completed installation of 21 RW/EWs (to date)
	Started foundation work for treatment building
	Started installation of single wall (reinjection line) and double wall (extraction line) piping
	Proposed phased approach to ETR: Phase 1 – 25 EWs, 23 RWs, Treatment Building (implemented) Phase 2 – Proposed second EW fence (not implemented)
Through 28 Feb 97	Conducted public presentations on ETR design
	Completed installation of 32 RW/EWs (to date)
Through 4 Apr 97	Submitted Draft Modeling Technical Memorandum
	Completed installation of 43 RW/EWs (to date)
	Continued foundation work for treatment building
Through 2 May 97	Completed installation of remaining RW/EWs
	Installed 7 additional monitoring wells
Through 30 May 97	Completed slab work for treatment building
	Installed 9 monitoring wells
	Initiated restoration activities
	Began erection of structural framing steel for treatment building
	Completed installation of major unit operations (GAC and greensand vessels)
	Completed hydro-testing of underground pipelines
	Completed installation of all well heads and EW pumps
	Completed engineering on outside chemical storage area and building fire detection system
Through 4 Jul 97	Completed all construction activities on Camp Good News prior to camp opening on June 25, 1997 (including pipeline installation, vault installation, vault mechanical, and vault electrical/instrumentation)

	Completed restoration on Camp Good News
	Completed erection of structural framing steel for treatment building and began installation of interior pipe racks
	Completed piping between GAC vessels; initiated piping between greensand filter vessels
	Submitted performance monitoring plan
Through 1 Aug 97	Completed installation of roofing panels for the treatment building
	Poured the foundation, pads and containment walls for the outside chemical storage area
	Issued Draft O&M manual to Commonwealth of Massachusetts, Classification Review Board
Through 29 Aug 97	Completed building installation
	Completed piping between unit operations
	Completed chemical storage area
	Completed electrical/instrumentation installation
Through 3 Oct 97	Completed paving at the treatment building
	Commissioned treatment building
	Completed baseline sampling
	Completed grading, seeding, and sod at the treatment building
	Continued restoration
Through 31 Oct 97	Completed installation of three microwells in Snake Pond and Weeks Pond
	Continued punch list items
	Completed installation of multi-port modems for communications
Through 28 Nov 97	Completed punch list items for the treatment building
	Continued communication diagnostics on the software and hardware for the treatment plant and between the plant and the wellfield
Through 2 Jan 98	Continued communication diagnostics on the software and hardware for the treatment plant and between the plant and the wellfield
	Began installation of the security fence around the chemical storage area and the treatment plant and construction and installation of the boundary fence between Camp Good News and MMR property
	Evaluated economics of operating UV oxidation and determined system was not necessary given the relatively low influent concentrations
Through 30 Jan 98	Continued preparation of record drawings
	Complete software configuration for communications
	Began preparing FS-12 Phase II Technical Memorandum Groundwater Modeling Report
Through 28 Aug 98	Continued work on FS-12 Phase II project
	Issued Final Performance Monitoring Evaluation Plan

TABLE 4-1. CHRONOLOGY OF EVENTS FOR FS-12 ETR SYSTEM

DATE	EVENT
December 1993	Draft Remedial Investigation Report, Volume III, Appendices E to O. Remedial Investigation/Feasibility Study, FS-12 Study Area
June 1994	Plume Response Plan (PRP)
25 September 1995	Final Record of Decision for Interim Action Containment of Seven Groundwater Plumes Signed (IROD)
October 1995	AS/SVE system began operation at Source Area
November 1996	Action Memorandum for FS-12 Source Removal Finalized
18 September 1997	FS-12 ETR system startup date (actual); AFCEE notified EPA of startup via letter
24 September 1997	FFA milestone for FS-12 ETR system startup (scheduled)
November 1997	Final Design Report for FS-12
November 1997 (system modification)	UV/OX system taken off line, H_2O_2 no longer in use at FS-12 treatment system
December 1997	Plume Response Program, FS-12 Containment System Design Report
January 1998	Quality Program Plan
February 1998	AS/SVE system ended operation at Source Area – closure sampling conducted in July, September, and November 1997.
April 1998	Final Performance Monitoring Evaluation Plan for FS-12
April 1998	Final Work Plan for Ecological Assessment Associated with Groundwater Plumes and Remedial Activities.
August 1998	Final FS-12 Groundwater Plume Phase II Pre-Operational Ecological Sampling Plan
September 1998	Draft FS-12 First Quarter Performance Monitoring Evaluation Data Report
October 1998	Draft FS-12 Phase II Technical Memorandum
October 1998	SD-4 North & FS-12 Groundwater Treatment Systems Operation and Maintenance Plan
October 1998	Final Technical Memorandum, Groundwater Modeling, FS-12
October 1998	Second Quarter 1998 FS-12 Performance Monitoring Evaluation (PME) Data Report
November 1998	Final Ecological Studies 1997 Annual Report for FS-12, SD-5, and CS-10 Groundwater Plumes
December 1998	Third Quarter 1998 FS-12 Performance Monitoring Evaluation (PME) Data Report
May 1999	FS-12 4th Quarter 1998 Data Report and Annual Performance Monitoring Evaluation.
June 1999	Final FS-12 Baseline Performance Monitoring Evaluation (PME) Data Report
June 1999	Final FS-12 First Quarter Performance Monitoring Evaluation (PME) Data Report
July 1999	System modification: FS-12 treatment plant reconfiguration to better utilize GAC
August 1999	Final May 1998 Ecological Assessment Report on the FS-12 and SD-5 North Treatment Systems
August 1999	FS-12 First Quarter 1999 Performance Monitoring Evaluation (PME) Data Transmittal
September 1999	Final August 1998 Ecological Assessment Report on the FS-12 and SD-5 North Treatment Systems
September 1999	Army sampled several FS-12 monitoring wells and microwells as part of an explosives investigation – detected EDB in microwell ECMWSNP02D.
November 1999	1999 Second Quarter System Performance and Semiannual Ecological Impact Monitoring (SPEIM) data Transmittal for the FS-12 Treatment System
December 1999	Final Fuel Spill-12 Treatment System 1998 Annual Ecological Assessment Report
January 2000	FS-12 Third Quarter 1999 Performance Monitoring Evaluation (PME) Data Transmittal
February 2000	Army reported EDB detection in microwell ECMWSNP02D above MCLs
March 2000	Final Installation Restoration Program FS-12 Source Area Removal Action Summary Report
March 2000	AFCEE confirms Army's detection of EDB in microwell ECMWSNP02D and also detects EDB in 02S at concentrations above MCLs – Special investigation begins.

May 2000	Final FS-12 Phase II Technical Memorandum
June 2000	FS-12 Treatment System 1999 Annual System Performance and Ecological Impact Monitoring Report
August 2000	FS-12 Quarterly System Performance and Ecological Impact Monitoring Report, January – March 2000
October 2000	FS-12 Quarterly System Performance and Ecological Impact Monitoring Report, April – June 2000
December 2000	Approval obtained from regulatory agencies to discontinue ecological sampling
December 2000	AFCEE awards contract to Jacobs Engineering to design and construction system modification to address EDB zones west of main FS-12 plume
January 2001	Final FS-12 1999 Annual SPEIM Report
August 2017	Cleanup goals projected to be achieved for groundwater restoration

TABLE 5-1. CUMULATIVE AND MONTHLY COC MASS REMOVED AT FS-12

Date	Cumulative Benzene Removed (pounds)	Cumulative EDB Removed (pounds)	Benzene Removed Per Month (pounds)	EDB Removed Per Month (pounds)
September-97	6.9	2.3	6.9	2.3
October-97	34.2	13.8	27.3	11.5
November-97	48.6	20.2	14.4	6.4
December-97	60.2	26.9	11.6	6.7
January-98	65.2	33.9	5.0	7.0
February-98	67.6	41.7	2.5	7.8
March-98	68.8	48.9	1.1	7.2
April-98	69.2	54.5	0.4	5.6
May-98	69.4	59.4	0.2	4.9
June-98	69.7	66.0	0.3	6.7
July-98	69.9	70.4	0.2	4.4
August-98	70.5	74.5	0.6	4.0
September-98	70.8	78.3	0.3	3.9
October-98	71.0	83.1	0.2	4.7
November-98	71.1	85.7	0.1	2.6
December-98	71.1	89.0	0.0	3.3
January-99	71.1	91.4	0.0	2.4
February-99	71.1	92.8	0.0	1.4
March-99	71.2	94.2	0.1	1.4
April-99	71.2	95.3	0.1	1.1
May-99	71.2	96.2	0.0	0.9
June-99	71.3	97.3	0.1	1.1
July-99	71.4	98.7	0.1	1.4
August-99	71.5	100.2	0.2	1.5
September-99	71.6	101.9	0.1	1.7
October-99	71.6	103.7	0.0	1.8
November-99	71.6	105.4	0.0	1.7
December-99	71.7	106.9	0.1	1.5
January-00	71.7	108.6	0.0	1.6
February-00	71.7	110.0	0.0	1.4
March-00	71.7	111.1	0.0	1.2
April-00	71.7	112.4	0.0	1.3
May-00	71.7	113.4	0.0	1.0
June-00	71.7	114.3	0.0	0.9
July-00	71.7	115.8	0.0	1.5
August-00	71.7	116.7	0.0	0.9
September-00	71.7	117.7	0.0	1.0
October-00	71.7	118.7	0.0	1.0
November-00	71.7	119.5	0.0	0.8
December-00	71.7	120.4	0.0	0.9

TABLE 7-1. FS-12 PLANT MONITORING

		E504.1 (EDB)	SW8260 (VOC)	E160.1 (TDS) / E160.2 (TSS)	ILM 04.0 (Fe & Mn)	E310.1 (Alkalinity)	E415.1 (DOC)	E415.1 (TOC)	A4500B (NO_2N), A4500E (PORTHO), A4500F (NO_3N), A4500H (NH_3N), MCTNP (Total N/P)	pH, Temperature, Dissolved Oxygen, Conductivity, Turbidity, & Oxidation/Reduction Potential
	Bottle Requirements	2 x 40 mL Amber	2 x 40 mL VOA	1 x 1 Liter Plastic	1 x 1 Liter Plastic	250 mL Plastic	3 x 40 mL VOA	3 x 40 mL VOA	1 x 250 mL Amber	Beaker
	Preservative	4 Deg C	4 Deg C	4 Deg C	pH <2 w/ HNO3	4 Deg C	pH <2 w/ H2SO4	pH <2 w/ H2SO4	4 Deg C	None
	Analyzed via	Lab (onsite)	Lab (onsite)	Lab (offsite)	Lab (offsite)	Lab (offsite)	Lab (offsite)	Lab (offsite)	Lab (offsite)	YSI
	Turn Around Times	24 Hour	24 Hour	21 Day	21 Day	21 Day	21 Day	21 Day	28 Day	Not Applic.
	Matrix	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)	Wastewater (WW)
	Sample Type	Grab (G)	Grab (G)	Grab (G)	Grab (G)	Grab (G)	Grab (G)	Grab (G)	Grab (G)	Grab (G)
	Field Filtered	NO	NO	NO	NO	NO	YES	NO	NO	NO
Weekly Requirements	Influent									X
	Post Caustic Addition									X
	Post Greensand Filter									X
	Post Lead Carbon #1									X
	Post Lag Carbon #1									X
	Post Lead Carbon #2									X
	Post Lag Carbon #2									X
	Post Lead Polishing Carbon									X
	Post Lag Polishing Carbon									X
	Effluent									X
Monthly Requirements	Influent	X	X	X	X	X	X	X	X	X
	Post Caustic Addition									X
	Post Greensand Filter									X
	Post Lead Carbon #1									X
	Post Lag Carbon #1	X	X							X
	Post Lead Carbon #2									X
	Post Lag Carbon #2	X	X							X
	Post Lead Polishing Carbon	*C*								X
	Post Lag Polishing Carbon	*C*								X
	Effluent	X	X	X	X	X	X	X	X	X

C = conditional event = TBD by WJK
highlighted text = direct impact monitoring (Delivery Order 30)

TABLE 7-2. FS-12 EXTRACTION AND REINJECTION WELL FLOW RATE DATA

Well	Design Flow Rate (gpm)	Operational Flow Rate* (gpm)	Comment
EW1	0	0	Well casings installed but never operational
EW2	0	0	
EW3	0	0	
EW4	0	0	Well never installed
EW5	0	0	Well never installed
EW6	32	0	Well shut down in June 00. See Section 2.3.2.
EW7	32	31	
EW8	37	36	
EW9	37	29	
EW10	20	0	Well shut down in June 00. See Section 2.3.2.
EW11	20	20	
EW12	20	45	Pumping rate increased due to EDB detections in zones outside of main FS-12 Plume. See Section 2.3.2.
EW13	27	27	
EW14	20	23	
EW15	20	21	
EW16	20	20	
EW17	25	38	Pumping rate increased due to EDB detections in zones outside of main FS-12 Plume. See Section 2.3.2.
EW18	25	38	
EW19	25	31	
EW20	10	15	Pumping rate increased to achieve design flows
EW21	10	15	Pumping rate increased to achieve design flows
EW22	25	26	
EW23	30	30	
EW24	40	36	
EW25	40	40	
EW26	40	39	
EW27	43	42	
EW28	55	55	
EW29	60	64	
EW30	50	54	
RW1	0	0	Wells never installed
RW2	0	0	
RW3	0	0	
RW4	0	0	
RW5	23	0	Wells turned off on July 25, 2000 due to EDB detections in zones outside of main FS-12 Plume. See Section 2.3.2
RW6	23	0	
RW7	34	0	
RW8	40	0	
RW9	46	0	
RW10	53	0	Well turned off on November 14, 2000 due to EDB detections in zones outside of main FS-12 Plume. See Section 2.3.2
RW11	0	0	Wells not installed due to difficult terrain
RW12	0	0	
RW13	53	82	Rates increased as a result of turning off RWs 5-10. See Section 2.3.2.
RW14	43	84	
RW15	33	83	
RW16	47	82	
RW17	47	82	

RW18	47	11	Rate adjusted in response to other RW adjustments due to EDB detections in zones outside of main FS-12 Plume. See Section 2.3.2
RW19	0	0	Well never installed
RW20	45	17	Rate adjusted in response to other RW adjustments due to EDB detections in zones outside of main FS-12 Plume. See section 2.3.2
RW21	45	17	
RW22	38	16	
RW23	33	17	
RW24	24	17	
RW25	21	17	
RW26	21	17	
RW27	21	13	
RW28	13	73	Rates increased as a result of turning off RWs 5-10. See Section 2.3.2.
RW29	7	75	
RW30	7	38	

* Flow rates at of January, 2001
EW = Extraction Well
RW = Reinjection Well

TABLE 7-3a. PUMP PERFORMANCE THRESHOLD

In-Plume System Threshold	Containment System Threshold	Action	Schedule
Pump operating at more than 10% below pump curve (head & flow)	Flow control valve 100% open (all systems)	Repeat inspection	Within three months after inspection or after detection of condition
Pump operating at 10% to 25% below pump curve	Pump operating at more than 5% below design flow or 10% below total dynamic head at design flow	Shock treat pump if scaling is not a problem	Within three months after inspection, or coordinate with the next breakthrough
Pump operating greater than 25% below pump curve or unacceptable improvement from shock treatment	Pump operating greater than 25% below pump curve or unacceptable improvement from shock treatment	Full-scale maintenance	Schedule for service immediately after inspection or trigger

TABLE 7-3b. EXTRACTION WELL PERFORMANCE THRESHOLD

Threshold	Action	Schedule
Up to a 25% decline in specific capacity below original value	Repeat inspection to evaluate rate of decline	Within three months after inspection
Specific capacity decline greater than 25% below original value	Full-scale maintenance	Schedule for service immediately after inspection

TABLE 10-1. FS-12 CONTACT INFORMATION

ENVIRONMENTAL PROTECTION AGENCY	DEPARTMENT OF ENVIRONMENTAL PROTECTION
Paul Marchessault, RPM H10, One Congress Street, Suite 1100 Boston MA 02203-0001 Phone: 617-918-1388 Fax: 617-918-1294 Marchessault.paul@epamail.epa.gov	Len Pinaud, RPM 20 Riverside Drive Lakeville MA 02346 Phone: 508-946-2871 Fax: 508-947-6557 Leonard.pinaud@state.ma.us
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE	**EPA CONTRACTOR**
Robert M. Gill, RPM HQ AFCEE/MMR 322 East Inner Road Otis ANG Base MA 02542 Phone: 508-968-4670 Fax: 508-968-4673 Email: robert.gill@mmr.brooks.af.mil	TRC Environmental Corporation Boot Mills South Foot of John Street Lowell MA 01852 Phone: 978-970-5600 Fax: 978-453-1995
JACOBS ENGINEERING	
Eric Banks, Program Manager Jacobs Engineering 318 East Inner Road Otis ANG Base, MA 02542 Phone: 508-564-5746 Fax: 508-564-6425 Email: eric.banks@jacobs.com	

APPENDIX B. REFERENCES

Air Force Center for Environmental Excellence (AFCEE). 1996 (July). *Strategic Plan.* Massachusetts Military Reservation, Installation Restoration Program.

_____. 1996 (November). *Final Action Memorandum AOC FS-12 Source Removal.* Prepared by Hazardous Waste Remedial Action Program for AFCEE/MMR, Installation Restoration Program, Otis ANG Base, MA.

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_____. 2000 (March). *Final Installation Restoration Program FS-12 Source Area Removal Action Summary Report, Massachusetts Military Reservation, Cape Cod, Massachusetts.* Prepared by Advanced Infrastructure Management Technologies for AFCEE/MMR, Installation Restoration Program, Otis ANG Base, MA.

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_____. 2001 (January). Final Fuel Spill-12 Treatment System 1999 Annual System Performance and Ecological Impact Monitoring Report. Prepared by Jacobs Engineering for AFCEE/MMR, Installation Restoration Program, Otis ANG Base, MA.

Air National Guard (ANG). 1995 (January). *Remedial Investigation Report. FS-12 Study Area.* Three Volumes. Prepared by Hazardous Waste Remedial Action Program for ANG Readiness Center, Installation Restoration Program, Otis ANG Base, MA.

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OpTech. 1996 (August). *Installation Restoration Program, Plume Containment Design Groundwater Modeling Report, Massachusetts Military Reservation.*

APPENDIX C. INSPECTION REPORTS

CH2MHILL TRANSMITTAL

To: AFCEE/MMR
322 East Inner Road
Otis ANG Base, MA 02542-5028

From: Stephen G. Brand
CH2M HILL
c/o Installation Restoration Program
HQ AFCEE/MMR
322 East Inner Road
Otis ANG Base, MA 02542

Attn: Rose Forbes

Date: February 21, 2001

Re: Transmittal of File Document: Pre-Final Close-out of FS-12 and SD-5 Plant and Well Construction

We Are Sending You: File document: Pre-Final Close-out of FS-12 and SD-5 Plant and Well Construction. Dated December 5, 1997

If material received is not as listed, please notify us at once

Rose,

Here is the document you requested from the Title II oversight files. If you need anything else, please let us know.

Copy To:Jason Alves

Stephen G. Brand
Project Manager, Title II Oversight

Stephen G Brand

Pre-Final Close-out of FS-12 and SD-5 Plant and Well Construction

TO: Jon Davis /AFCEE
Lee Perry/AFCEE
Ed Pesce/AFCEE

COPIES: Mike Curtis/CH2M HILL
Dave Herlihy/CH2M HILL
Stephen Brand/CH2M HILL

FROM: Cliff Bell/CH2M HILL

DATE: December 5, 1997

This memo summarizes closeout of FS-12 and SD-5 Extraction Treatment and Reinjection (ETR) plant and well construction inspection services performed by CH2M HILL at the Otis Air National Guard Base. The services were part of an agreement for CH2M HILL to provided Remedial Design Title II support for the Installation Restoration Program (IRP) of the Air Force Center of Environmental Excellence (AFCEE) at the Massachusetts Military Reservation (MMR). The memo should be considered to effectively represent the completion of Title II inspection services performed at Otis during fiscal year 1997. The period of performance of inspection work began in December 1996 and daily site inspection activities can be considered concluded as of the date of this memo.

Pre-final Inspection

On Friday, November 14, the pre-final inspection of the SD-5 and FS-12 ETR systems was performed per the SOW; Section 4.4.2.4.2 Inspections. Details regarding the pre-final inspection conducted are included in the section below entitled "Walk-through Inspection for FS-12 and SD-5".

Final Inspection of Plant and Final Inspection Report

As per the memo from Jon Davis to CH2M HILL on Nov. 18, 1997 this closeout memorandum should serve the purpose of the final inspection report called for in paragraph 4.4.2.4.3 of the CH2M HILL Statement of Work (SOW) attached to modification 04 of delivery order 00034. It is our understanding, however, that a final inspection of specific items may be scheduled and conducted at a later date. Unless called upon to provide this inspection, this report will serve the purpose of the final inspection report. The as-built drawings and documentation will be provided to AFCEE by Jacobs and it is our understanding that no further action is required by CH2M HILL to complete this documentation.

The CH2M HILL files including daily and weekly inspection reports of plant and pipeline construction and resident engineering construction correspondence and documentation is

located in a four drawer cabinet in the CH2M HILL office area. A copy of "Resident Engineering File Directories" is included in the cabinet and is attached to this memo.

Well Construction Oversight

Site inspection of well and vault construction was performed at the FS-12 and SD-5 ETR plant sites. Pre-final inspection of well construction is not made possible by virtue of their installation below ground. A "punchlist" of outstanding items (as presented later in this memo for resident engineering plant inspection) was not generated for well construction. Well construction and well material issues, however, have been highlighted in prior memos. We consider these issues to be open items.

A pre-final walk-through of vaults was not conducted. Issues relating to vault construction are listed in the "Walk-through Inspection for FS-12 and SD-5" discussion. CH2M HILL Title II services this year also included oversight at the CS-10 and Ashumet Valley recirculation well pilot locations and at design investigation locations at the southwestern toe of CS-10, Ashumet Valley and at LF-1. Daily and weekly reports summarizing well construction activities at each of the above sites and the ETR plant locations can be found in a four door file cabinet located at the IRP. A copy of "Well Construction Inspection File Directories" is included in the file cabinet and is attached to this memo.

Performance Standards

As per Jon Davis's memo of November 18 CH2M HILL is not required to provide documentation regarding performance standard verification. Special mention of total design flowrate of FS-12 was made by Ed Pesce, Project Manager, during the plant walk-through. This is addressed as item 9 in the discussion under "Walk-through Inspection for FS-12 and SD-5".

Walk-through Inspection for FS-12 and SD-5

The walk-through conducted on November 14 was attended by the following participants:

AFCEE	JACOBS	CH2M HILL
Jon Davis	Alan Alai	David Herlihy
Lee Perry	J.J. Cameron	
Ed Pesce	Larry Eitel	
	George Peterson	
	Don Taft	

The pre-final inspection consisted of a walk-through of the SD-5 and FS-12 treatment plants to perform a physical inspection of the facilities and a review of all previously identified outstanding work items compiled from punch lists, Nonconformance Reports, Warranty Items, To Do Items, and CH2M HILL issues (See Attachment entitled "Outstanding Work Items"). It is our assessment that Jacobs has the action to close out all items identified in this report and the "Outstanding Work Items". Items that were resolved and verified by Jacobs and CH2M HILL during construction and start up are not shown on the "Outstanding Work Items". Several items which appear as outstanding work items are

dependent on funding for closure and others are weather related. It is our understanding close out of some items is not scheduled until spring of 1998.

No new items were added to the list as a result of the walk-through. The following items were discussed in detail:

1. Software issues were discussed in detail. The vendor has been trying to improve the system operation, but the computer continues to "lock up" and while it is possible to read FS-12 data at a computer at SD-5, it is not yet possible to issue commands to the system. Jacobs will either correct the present software or replace the server platform if required. Their vendor is responsible to provide a fully functional system.
2. The surface durability of the asphalt paving at SD-5 was questioned and an extension of the warranty to two years was obtained by Jacobs from the subcontractor, Lawrence Lynch. A similar condition exists at F-12 and Jacobs will obtain a warranty extension at this site as agreed to by AFCEE.
3. The relocation of the flow meters in the reinjection well vaults will be performed by Jacobs Operations and maintenance personnel. To date, only one flow meter at SD-5 has been relocated which did resolve the problem of erroneous flow readings.
4. The rafter end plate connections in the buildings do not have full contact bearing surfaces. The building supplier and engineer of record has been asked several times to verify that these connections are in accordance with the design. Jacobs will obtain this verification stamped off by their Professional Engineer or have repairs made as necessary to obtain compliance to the design.
5. Rust on the piping has appeared between Tank T102 and P102 at both units. Jacobs will have this repaired as a warranty item.
6. The UV OX System piping welds were satisfactorily repaired. Jacobs will operate the system at low levels of hydrogen peroxide and evaluate the performance. A final determination of for UV OX operation will be made pending the results.
7. The Operating and Maintenance manuals have been prepared by Jacobs and the draft edition is ready for transmittal to AFCEE for review and comment by the interested parties.
8. Vault manhole covers include cast iron "dogears" or moldings into which each of 6 bolts seat and therefore provide security. Dogears on several of the vaults have cracked and or broken away from the cover. After being brought to the attention of AFCEE it was agreed that action need not be taken given that the practice associated with breaking the dogears has been corrrected and the vaults are otherwise secure with the dogears that remain.
9. A major performance goal is the operation of FS-12 at the design parameters for this unit. The unit has not operated at the 1050 GPM design level. It is our understanding Jacobs will arrange to operate the unit at full design capacity in the near future. A scheduled date was not discussed during the walk-through.

All other items on the list were reviewed and discussed and appropriate action is planned.

	OUTSTANDING WORK ITEMS				
CATEGORY	ITEM DESCRIPTION	SITE	RP	RESOLUTION	FURTHER ACTION
PUNCH LIST					
	#220 - PAINT BOLTS ON T101,102,&103	5	O&M		ALSO DO AT FS-12
	#266 - RESOLVE ISSUE W/PAVEMENT	5	WC	LAWRENCE LYNCH	ALSO AT FS-12
	#297 - FURNISH GND. SYS. TEST REPORTS	5	WC		
	#144 - FURNISH GND. SYS. TEST REPORTS	12	WC		
	#174 - REPLACE LENSES ON FLORESCENT	12	WC		
	LIGHT FIXTURES				
	SEAL CONDUIT IN ALL WELL VAULTS	5&12	SPARKS		
NCR					
	#10 - PAINT ON TANK 1T-102	12	JE	TOUCH UP	
	#11 - PAINT ON TANK 1T-105	12	JE	TOUCH UO	
	#12 - PAINT ON TANK 1T-101	12	JE	TOUCH UP	
	#16 - PAINT ON CALGON 1CF-101A/B, 102A/B,103A/	12	GP	CALGON	
	#17 - PAINT ON CALGON FAB PIPE	12	GP	CALGON	
	#18 - PAINT ON CALGON FAB. PIPE	5	GP	CALGON	
	#19 - PAINT ON CALGON 2CF-101A/B, 102A/B	5	GP	CALGON	
	#28 - PAINT ON TANK 2T-101	5	JE	TOUCH UP	
	#29 - PAINT ON TANK 2T-102	5	JE	TOUCH UP	
	#39 - PAINT ON CARBON FILTER TANKS T102A/B	5	GP	CALGON	
	DID NOT ADHERE				
	#62 - UV/OX SYSTEM WELDS	12	GP	COMPLETED-NEED	JE QA/QC SIGN OFF
WARRANTY					
	FIX VENT AND LIGHTS IN BATHROOM	12	WC		
	REPAIR ELEC OUTLET IN H202 AREA	12	WC		
	REPAIR CHECK VALVE 1P-101C	12	WC		
	REPAIR LEAKS ON VENT STACKS	5,12	WC		
	REPAIR GAS VALVE ON REZNOR HEATER	5	WC		
	RESOLVE SOFTWARE ISSUE-GENESIS	5,12	RAWSON		
	REPAIR LEAK AT H2O2 TANK	12	WC	WAITING FOR TANK DRAWDOWN	
	KMNO4 "B" PUMP CYCLES	12	USFILTER	JE EVALUATING	
	PAINT ON BOTTOM OF KMNO4 SKID FAILED	12	USFILTER		
TO-DO ITEMS					
	CHECK HEAT TRACE OPERATION	12,5	O&M		
	FILL LOW SPOT ON CGN ROAD	12	JRT		
	ADJUST NATURAL GAS PRESSURE	5	O&M	COLONIAL GAS NOTIFIED	
	INSTALL FENCE BETWEEN CGN AND MMR	12	JE	$43K FUNDED- SCHEDULED MAR 98	
	RESTORATION OF SD-5	5	JE	$20 K FUNDED-SCHEDULED IN MAY 98	
	INSTALL FENCE AROUND CHEMICAL AREA	12	JE	$7973 FUNDED-SCHEDULED FOR APR 98	
	RELOCATE FLOW METER IN REINJECTION VAULT	12,5	O&M		
	INSTALL PERIMETER FENCE @ PLANT	5	JE	$29450 FUNDED-SCHEDULED ASAP	
CH2M HILL	VERIFY RAFTER PLATE CONNECTION O.K.	5,12	WC	NEED LTR FROM ENG. OF RECORD	
ISSUES	RESTORATION AT OLD GREENWAY ROAD	12	JE		
	INSTALL LIGHTNING PROTECTION	5,12	JE	$41K FUNDED-WILL START ASAP	
	VAULT MANHOLE COVERS-BROKEN EARS	12	JE		
	RUST ON PIPE BTN P102 AND T102	5, 12	JE	REVIEW	

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028

11 April 2001

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FROM: HQ AFCEE/MMR
322 East Inner Road, Box 41
Otis ANG Base, MA 02542-5028

SUBJECT: Final Report

1. Attached please find the document entitled "Final Fuel Spill-12 Interim Remedial Action Report" dated 11 April 2001.

2. If you have any further questions, please call Rose Forbes at (508) 968-4670, extension 5613.

Sincerely

Robert M. Gill

ROBERT M. GILL
Remediation Program Manager

Attachment:
Final Document

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